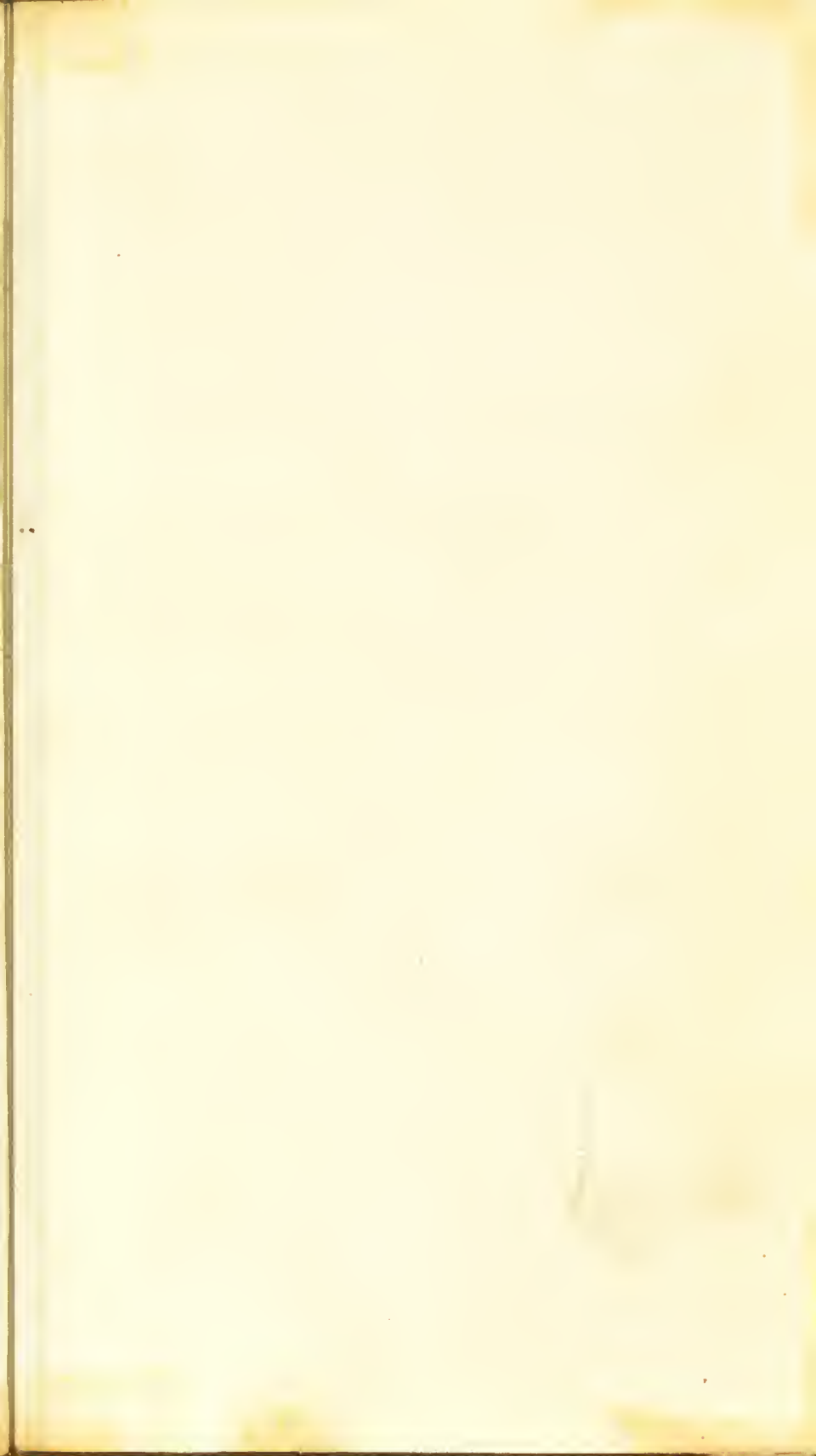
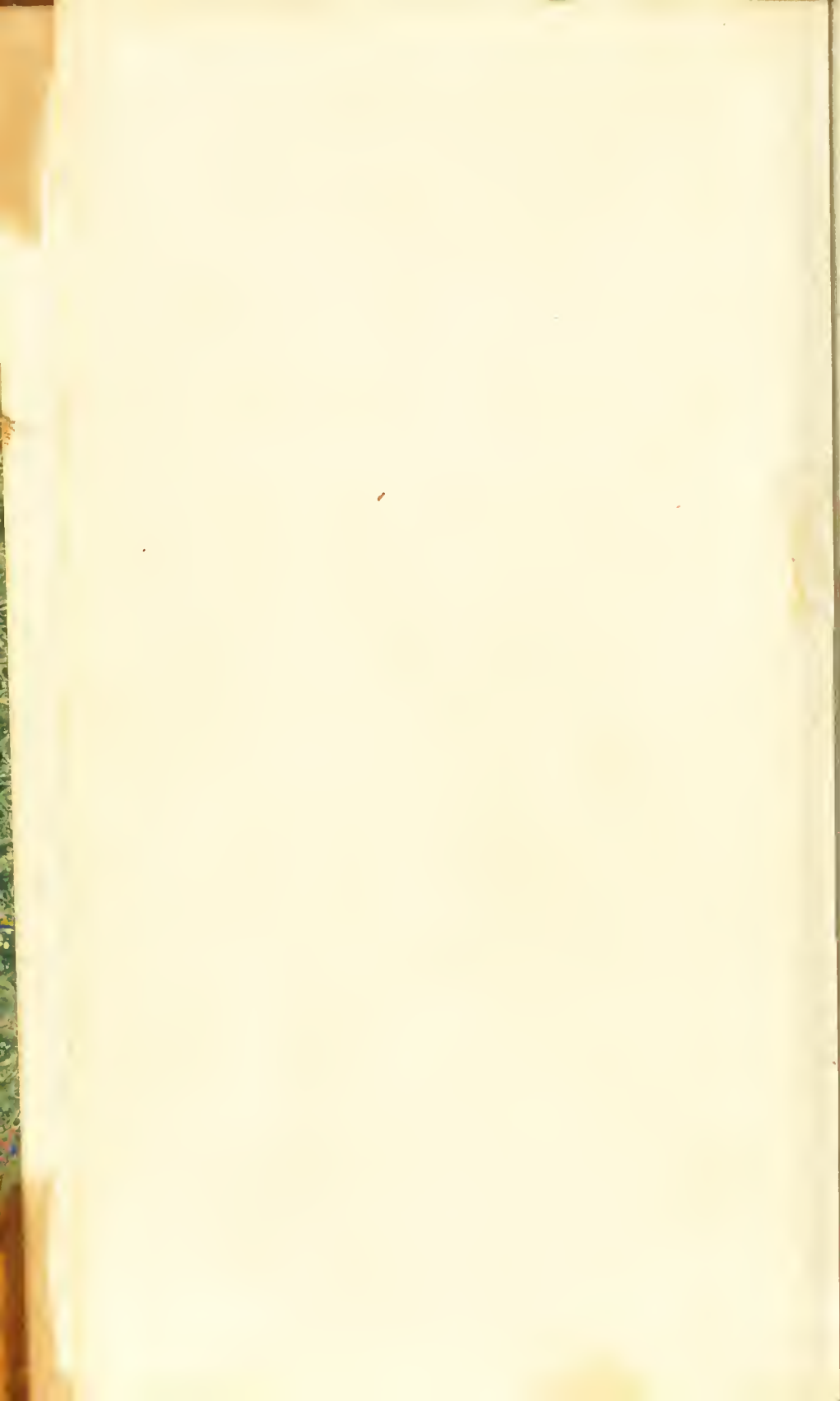




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A  
SERIES  
OF POPULAR  
CHYMICAL ESSAYS:

Containing a Variety of Instances of the  
Application of Chymistry to Arts and Manufactures;  
the Explanation of natural Phænomena; and  
to other useful Purposes

---

BY

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TO THE

GOVERNORS, and other SUBSCRIBERS,

OF THE

*KETTERING DISPENSARY,*

FOR

THEIR READY AND LIBERAL ASSISTANCE

IN PROMOTING THE ESTABLISHMENT,

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USEFUL AND CHARITABLE INSTITUTION,

*THIS HUMBLE EFFORT*

OF THE AUTHOR,

TO DIFFUSE USEFUL INFORMATION,

IS GRATEFULLY DEDICATED

BY THEIR HUMBLE SERVANT,

*Kettering,*  
Oct. 7th, 1802.

*FENWICK SKRIMSHIRE.*





## PREFACE.

THE substance of the present essays is part of the materials, collected by the author with a view of delivering an experimental course of popular lectures on Chymistry and Natural History: Professional engagements having prevented the adoption of his intended plan, it was thought by him, that it might prove acceptable to the public in the present form.

It is not to be considered as a strictly scientific work, but rather as one adapted to convey useful information to the class called *general readers*, by which is meant, those who are desirous of an acquaintance with various literary and scientific subjects, without entering into the minutiae of any science.

The subjects, here treated of, being elucidated and explained upon their true principles, the work is calculated to remove many erroneous conceptions concerning common occurrences.

By pointing out very frequent applications of chymical knowledge to useful purposes, the reader will be led to form a notion of the extensive utility of the science; and by preserving a connection between the subjects of the different essays, it is presumed that he will have formed a general idea of the whole system of Chymistry.

Should the view, that is here given, excite a single reader to a further prosecution of the study, or should the subject, as here treated, be the means of diffusing information, that is at all useful, the author's ambition will be fully gratified.

Subjects connected with Chymistry are so numerous, that the work might easily have been swelled to a much larger size; but by attempting too much, we frequently effect nothing. It is hoped that the selection will be thought judicious.

The present work differs essentially from the scientific and well-received "Chymical Essays" of Dr. Watson. He has given complete essays on single detached subjects, whereas the author of the present work has introduced a very great variety of interesting matter into each essay, and has connected the different essays together into a series. He has also been careful to select subjects, that are more generally interesting.

In a work of this kind the materials must of course be collected from a variety of authors, whom it would be useless and tire-

some to quote. Chaptal, Priestley, Saussure, Pictet, Fourcroy, St. Fond, Rumford, Kirwan, Bancroft, Saunders, and many others, have been occasionally had recourse to; and some of the experiments related by Mr. Henry, in his valuable Epitome of Chymistry, have been selected as appropriate, and particularly correct.



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## ESSAY I.

### THE OBJECT AND UTILITY OF CHYMISTRY.

To the student, desirous of information, two questions naturally arise on hearing the name of any science, profession, or art, which has not been the subject of his studies. He first inquires what is the *object* of this science, profession, or art, and what kind of information it affords. He then as eagerly demands to be informed of its *utility*.

Suppose geography to be the science; what is geography? he asks; what does it teach? or what does a knowledge of it imply? Geography, he is told, is the science, that teaches us the division of the globe into land and water; the former into kingdoms, and smaller portions; the latter into seas, lakes, and rivers; and then teaches us the relative situation of these various parts. What is the advantage of this knowledge? is the next question; and he is told in answer, how much the traveller is benefited by it in traversing distant regions; how useful it is to the general marching into an enemy's country; how necessary to the student of natural history; and how requisite to the philosopher, studying the manners, moral and political, of different nations.

If astronomy is the subject of inquiry, the same questions arise; and he is informed that its object is, to teach the situation and motion of the sun, planets, and other heavenly bodies; their situation with respect to the earth, and to each other; and their motion in their respective orbits, as well as on their own axes. As to the advantage of such knowledge, it is various, and important. It enables us to foretel the change of seasons, as well in countries that we never visited, as in our own; to explain and to predict various natural phenomena, as eclipses, conjunctions of the planets, and the appearances of comets; and by the aid of calculation it teaches the navigator to steer his course through unknown seas, and to ascertain his precise situation either on the ocean, or on the land, though in climes never before visited by man.

Similar questions to the above must naturally arise respecting other sciences; and the anticipation of them respecting chymistry will furnish us with matter for the present essay; forming an appropriate, and, I trust, interesting introduction to the rest.

In pointing out the object and utility of *chymistry*, I shall explain in a general way the advantages that have been derived from it, in its extensive application to the arts; and the assistance it affords us in explaining a variety of



natural phenomena, and in studying the other sciences.

CHYMISTRY, to define it, or express its object in a few words, may be said to teach us, *the changes that are effected in the component parts of bodies by their mutual action*. But as definitions are always dry, and the best may become the subject of cavil and dispute, I shall endeavour to illustrate and explain my meaning by the relation of a few simple experiments.

When a piece of marble or a piece of chalk is dropped into a glass of aqua fortis or a glass of vinegar, an effervescence immediately takes place, or the liquor froths, in consequence of the extrication of air or gas; the marble or chalk is gradually dissolved, and the liquor at length remains clear and transparent. Certain changes have here been effected in the component parts of the marble and the acid, by their mutual action of the one upon the other; and it is the object of chymistry to teach, both what these changes are, and how they have been effected. What is called *practical chymistry* teaches us the first, and *theoretical chymistry* the second part.

This action of the acid upon the marble, and of the marble upon the acid, differs materially from any kind of mechanical action, and is called a *chymical action*. For instance, it differs materially from the mere diffusion that takes place



when sand and water, or oil and water, are agitated together in a phial. By shaking they are made to act *mechanically*, and for a moment the sand or the oil is diffused through the water; but no sooner do you cease to agitate them, than they instantly separate; the sand subsides to the bottom, or the oil swims on the surface of the water. But with respect to the marble and the acid, the former is not merely diffused; they have acted *chymically*, and the marble will not be deposited on standing, nor can they be again separated but by other *chymical* actions.

The peculiarity of this kind of action, in which it differs from other kinds, is, that it only takes place at immeasurable and intensible distances; it being necessary to *chymical* action, that the particles of one body should be in close contact with those of the other. Hence it follows, that few solids can be made to act *chymically* on each other, a fluid and solid more easily, and two fluids still more so, because their particles are more readily brought into contact.

Instances however may be brought of *chymical* action between substances in all these forms; and we shall select for examples such as will prove very amusing and interesting experiments. As an instance of two solids being brought to act *chymically*, rub together in a mortar small portions of brimstone and the oxymuriate of potash.

By trituration they are made to act on each other, and the consequence is repeated flashes, and slight explosions. A small portable apparatus for performing this experiment may be had at the shops in London.

As an instance of a solid and a fluid, drop some potash into an infusion of roses; and as an example of two fluids, pour an acid into the same infusion: by the former the red liquor will become green, and by the latter addition it will recover its original colour, or rather become bright red: this change may be repeated on the same liquor as often as you please by the alternate addition of an alkali and an acid.

As another example of two fluids acting chymically on each other, mix together a saturated solution of Epsom salt in water, and a saturated solution of muriate of lime. In this experiment the two transparent fluids are suddenly converted into one solid mass, and that without freezing.

Lastly, as an instance of chymical action between two gasses or aëriform fluids, mix the common air of the atmosphere with nitrous gas, as in the common eudiometer, and a diminution of volume, and formation of nitrous acid, instantly take place.

The above experiments are all examples of chymical actions; and it is the object of chymistry to ascertain, and to explain, the various changes that have taken place in them.

When two simple bodies are made to unite chymically, we call the substance resulting from the union a *compound*. This compound may again unite either to a simple or to another compound, forming in the first case a triple substance, or in the last a compound of four simples; and these again may unite to others, forming substances still more compound.

Now it is one of the grand objects of chymistry, to separate these compounds into the simple elements, of which they are composed; and the operation by which it is performed, is called *analysis*.

When we have accurately analysed any compound substance, we may often reproduce it by properly combining the simple substances, of which we have discovered it to be composed. This process is termed *synthesis*, which in the investigation of any chymical substance forms with the former, namely analysis, the complete chymical test.

Of what I have here said I shall now give an example in the decomposition and recomposition of Epsom salt. By dissolving it in water, and then adding an alkali, the fossil alkali, called soda, for example, an earthy powder is precipitated, which, when collected by filtering the liquor through paper, is found by particular chymical tests to be magnesia. The filtered liquor by further tests is discovered to be nothing but Glauber's

salt dissolved in water. Now Glauber's salt is known to be soda combined with sulphuric acid, or oil of vitriol, the former of which was added in the experiment. We have here *analysed* Epſom salt, and found its constituent parts to be magnesia and sulphuric acid.

If magnesia be dissolved in sulphuric acid, diluted with water, and the liquor evaporated, a salt is crystallised, that is found to be Epſom salt; so that we have here the *synthetical* proof, that Epſom salt is a combination of magnesia and sulphuric acid.

Some chymical substances have a greater disposition to unite than others, as sulphuric acid and soda, than sulphuric acid and magnesia, in the above experiment. This is termed their chymical *attraction*, or *affinity*; and in chymical language we say, that sulphuric acid and soda have a stronger affinity, than the former and magnesia; or we say that sulphuric acid has a stronger attraction for soda than for magnesia.

It is in consequence of these different affinities, that we are enabled to decompose one substance by the addition of another, as Epſom salt by the addition of soda; and it is the object of chymistry to teach the degrees of these affinities between different substances, whereby the chymist is able to foretel the consequence of mixing such and such substances,



together; and he who knows the most in these respects is the best practical chymist.

I have now explained the object of chymistry, and shall therefore proceed to point out some of the most striking instances of its utility, and its applicability to useful purposes.

Almost every art may be considered as a chymical process; and although we see many of them daily performed by the most ignorant people, and although some may have been originally discovered, and even brought to their present state, without any assistance from the chymist, yet they become to him interesting objects of attention; and it is only by his aid, that the nature of the process can be understood, and explained. It is by such knowledge that very many have been simplified, and improved; nor are the original discoveries of the chymist few or unimportant.

In the art of *dyeing*, every part of the process is chymical, and many improvements have been made in it by scientific men. Dr. Bancroft in this country, and Berthollet in France, have within these few years done much in simplifying the operations, and in rendering them less expensive. They have also improved the dyes in some cases, and introduced many new colouring drugs, the particulars of which will fall more properly to be noticed in an essay on this subject.

*Bleaching* again, which ten years ago was a process of many months, may now be less expensively and more completely performed in as many days. The discovery of oxygenated muriatic acid, by which this great improvement in the art of bleaching has been effected, was made by Scheele, a Swedish chymist; and Berthollet, a Frenchman, has the honour of having first applied it to this purpose; and various scientific men in this country have improved the mode of using it. Every manufacturer has now taken advantage of this discovery, by which the extensive bleach-fields are contracted, and their goods brought to a much earlier market.

*Tanning* is another art, that has been very much, and is likely to be still more improved, by having become the subject of chymical investigation. In tanning, the object is, to convert the soft and porous hide into a more hard and compact substance, that is less easily penetrated by water, and less liable to putrefaction. This has always been chiefly effected by long continued immersion in an infusion of some bark, most commonly oak bark. Seguin, a Frenchman, examining the nature of the process scientifically, and ascertaining the chymical qualities of the infusion, found that it is not, as generally believed, the astringent quality of the bark, that operates the change, but a distinct principle, now called the tanning principle, which ex-

ists in different proportions in the bark of different trees. This tanning principle he has devised the means of extracting, and applying to the hides in a more concentrated form, than it had hitherto been used; by which means hides, that required twelve or eighteen months, may now be tanned in less than as many weeks, and of course be brought to market at a much lower price.

In the making of *pottery* and *porcelain* every one must be aware of the great improvements that have been introduced within the last ten or twelve years; and it is generally known too, that to Mr. Wedgwood we are indebted for most of these valuable improvements. This scientific manufacturer accurately analysed the best foreign wares, to discover of what earths they were formed, and in what proportions; he examined in the same way different antique vases, and other articles, and by a very ingenious contrivance, which will be noticed in a future essay, he invented the means of ascertaining the exact degree of heat, to which any such articles had been exposed in their baking. He then sought through various parts of this country for earths, such as he wanted; what he could not find, he formed artificially by the due admixture of others; and, by all these means combined, he has been enabled to imitate the wares of China, and of other countries, that excelled us; and has invented different kinds, both



more ornamental and more useful, than what were before manufactured.

It will require little consideration to show the application of chymistry to *metallurgy*. None of the metals are found naturally pure and uncombined, at least not in any considerable quantity. They are united sometimes with sulphur, sometimes with pure air under the form of calces, sometimes with acids, and often with each other. Copper, for instance, is found in all these states; in the form of pyrites with sulphur, of calx with pure air, of blue vitriol with sulphuric acid, and often mixed with silver, and other metals. It is true that the means of separating and purifying many of them have been accidentally discovered by unscientific men; but with how much more certainty, and how much more simply, will he execute the business, who, acquainted with the affinities, and other laws of the substances he employs, knows exactly, what will separate their component parts, and what will purify them from adventitious matter. One or two instances of the advantage of chymical knowledge in this department will sufficiently evince the extensive applicability of it to metallurgy.

Copper is frequently found combined with vitriolic or sulphuric acid in the form of blue vitriol; and in the mines, where it is found in this state, there are frequently streams of water very much

impregnated with this copper ore, which were formerly thought uselefs, and were consequently neglected.

Chymiftry teaches us that fulphuric acid has a ftronger attraction for iron than for copper; of which fact you may eafily convince yourfelf by the following fimple experiment: Diffolve fome blue vitriol in water, and immerfe into this folution the blade of a knife, a key, or any other piece of polished iron, and you will prefently perceive its furface to be covered with a layer of copper, the acid of the vitriol having feized on the iron, and in the fame proportion depofited the copper. To apply this ufefully to the point in queftion, it is only neceffary to throw old ufelefs iron into thefe fstreams, and a depofition of good copper will be gradually effected; which is a plan, that is now very generally praftifed.

As another inftance, fomewhat fimilar to the former, of advantage derived from chymiftry, I fhall mention a mode of obtaining green vitriol adopted in a manufactory at Newcaftle. There is often found among the coals of that place a large quantity of an ore, called pyrites, which, as it injures the quality of the coals, is always feparated from them, and was heretofore confidered as ufelefs. The chymift has now taught the manufafturer to convert thefe pyrites into green vitriol, and has

thus rendered valuable what was before considered as useless.

The pyrites contain both iron and sulphur; green vitriol is a combination of iron and sulphuric acid; what is to be effected therefore is, to convert the sulphur into sulphuric acid, and dispose it to unite with the iron. This conversion only requires, that the sulphur should be made to combine with oxygen, or the pure part of the air, for sulphuric acid is sulphur acidified by oxygen, and the mode adopted in the present instance is as follows.

A large area of ground is enclosed, that has a gentle declivity; the surface is made even, and is covered with a fat clay, and a furrow is formed in the midst of it, to collect and convey the water to proper reservoirs. The pyrites are spread out in layers on this area to the height of some feet, and by exposure to the air, rains, and other vicissitudes of the weather, they soon heat, swell, and fall into powder. This operation is assisted by turning the pyrites with rakes, that have iron teeth, and by occasionally sprinkling them with water, when the season is dry. The sulphur by this process absorbs the oxygen or pure part of the air, which converts it into sulphuric acid. This acid seizes the iron, and forms green vitriol, which, dissolved in the water, is conveyed into the reservoirs. From these reservoirs it is carried to coppers, where it is boiled, and evaporated to a sufficient strength. It is then

crystallised by cooling in wooden troughs. This green vitriol, martial vitriol, or copperas, as it is often called, forms an article of traffic, and is used by dyers, and frequently by curriers, as also in many other of the arts; and it is a principal ingredient in the making of ink. It is likewise a very serviceable medicine in a variety of complaints.

In *brewing, baking, making wine, spirits, vinegar, &c.*, we have pure chymical processes, that can only be thoroughly understood by the chymist, and are consequently most likely to be improved by him. To enumerate and describe all the improvements made by chymists in these and other arts, would be improper in an introductory essay. I shall therefore now conclude the applicability of chymistry to operations of art, by a late improvement in the art of making vinegar in the large way.

It is a fact now well known, that beer, wine, sugar and water, and other such liquors, become sour, in consequence of their absorbing or imbibing the pure part of the air, or oxygen. It is also known, that the greater the surface of the liquor, that is exposed to the air, the more quickly it absorbs the pure part of it, and becomes sour. This therefore is the grand point that is to be aimed at in the whole process; and by constantly pumping the liquor into a large cooler, through which it is allowed to run in a slow stream, and return to the vat, from which it was pumped, the



surface thus exposed to the air is considerably greater than it would otherwise be, and the time of making the vinegar is thereby very considerably shortened. For the same reason, when it is made in the small way, the air should be freely admitted, and the cask be not more than half filled, that a greater surface may be in contact with the air.

The subserviency of chymistry to the other sciences might be expatiated upon very largely, but not without entering too minutely into the sciences themselves. *Medicine* has been benefited by it in a variety of ways, in the composition of remedies, as well as in the practice. Almost all the animal functions, as respiration, digestion, &c. are chymical processes, some perhaps peculiarly modified by the principle of life. Our breathing is a chymical process, that until lately was hardly at all comprehended. The diseases of the chest, where the organ of respiration is seated, will naturally be supposed to be connected in a great measure with the state of that function. This is certainly the case; and the physician therefore, who is ignorant of the nature of this chymical process, will be much less likely to employ the proper remedies, than one, who is well acquainted with this important function. Numberless such instances might be pointed out, to show the superiority of that part of the profession, that is well versed in chymistry, over such as know nothing of this science.

The *natural philosopher*, without the aid of chymistry, would form but an inadequate notion of the properties of air, water, fire, or light. He would know that the air of the atmosphere is elastic, ponderous, and more or less compressible; but he would be ignorant that it is a compound of a pure and an impure air, the first supporting combustion, and life by respiration, whilst the other is unfit for either.

The *mineralogist* requires chymical tests to discriminate between substances that to the eye appear similar, and to ascertain more fixed characters for distinguishing between one mineral and another.

Lastly, the *agriculturist* may derive advantage from chymistry by scientifically examining the nature of the soil, and the nature of his manures, and by these means learning properly to adapt the latter to the former.

I have now pointed out some very palpable examples of the useful application of chymical knowledge. To explain more fully the processes, that I have here only hinted at, will occupy some of the future Essays, in which I shall likewise select such others, as are likely to prove most interesting and most useful. I shall at the same time endeavour to preserve such a connection between the subjects of the different Essays, as shall convey a general idea, at least of the outlines, of the whole science of chymistry.

## ESSAY II.

## CHYMICAL ELEMENTS.

IN every age there have been certain substances considered by the philosophers of the day as elements, or simple substances, of which every thing else has been supposed to be compounded. But what have been enumerated by the philosophers of one age as elements, have been afterwards proved by those of another to be compounds; and as the science of chymistry has been improved, we have discovered the means of analysing or decomposing what was previously conceived to be a simple. Thus water, from time immemorial to a very late period, was allowed by all philosophers to be one of the elements of nature; modern chymists have however decomposed it, and detected with accuracy the ingredients of which it is formed, and even the proportions in which they exist. For many ages past, and even to this day by many, earth, air, fire, and water, have been, and are considered the four elements, of which this globe, and every thing terrestrial, are formed. Chymistry now teaches us, that there are many kinds of earth, and many kinds of air, perfectly distinct from each other, some of which



are compound, and some simple. It teaches us that fire, called now caloric, is a simple substance; and that water, as I said before, is a compound.

Although we can now treat more accurately of the elementary substances, we cannot speak decidedly; and you must still keep in mind, that what are at present termed elements, may by future chymists be discovered to be compounds; and that we only mean, by calling them so, to assert that, in the present state of chymical knowledge, they are not decomposable. The substances at present considered as elements are the following. Caloric (the matter of heat or fire); light; oxygen (the base of pure or vital air); azote (the base of impure air); hydrogen (the base of inflammable air); carbone, or pure charcoal; phosphorus; sulphur; two of the alkaline salts, viz. soda and potash; the nine earths; and all the metals.

As these are the simple substances at present known; a complete body of chymistry would be given, by treating of their various combinations with each other; and perhaps the most scientific system would be formed by treating of each simple substance separately, and noticing under the head of each all those compounds, that derive their most remarkable properties from that particular element.

Whether, however, this might or might not be the best mode of forming a complete system of

chymistry, it will afford a very convenient arrangement for the partial account intended to be given in the following Essays. It will afford us every opportunity, that can be wished for, of noticing such peculiarities in the properties both of the elements and their compounds, as will be thought worthy of attention; and will lead us to notice their uses, to explain any art to which they may be applicable, any science to which they may be subservient, or any phænomena which they may tend to elucidate. The same plan will also have the advantage of connecting one Essay with another, and forming of the whole a connected series, that will be calculated to give a general idea of chymistry as a science. The order, in which the elements have been enumerated above, is the order, in which they will be treated of; first then of *heat* and *light*.

## ESSAY III.

### THE CONNEXION OF HEAT AND LIGHT.

THERE is so intimate a connexion between heat and light, that we have in many instances the appearance of the one being converted into the other; they are frequently concomitants in the same phenomena; and the same causes in a variety of instances produce both.

This their intimate connexion has given birth to a variety of hypotheses; and various conjectures have been hazarded in consequence, respecting the nature both of heat and light. We must not however, in treating this subject, indulge in those speculative opinions, that have occupied in vain so much of the time and attention of philosophers, and concerning which there is still as much discordancy as ever.

We must pass over the long contended questions, whether heat is a mere vibration of particles, or a particular substance; whether it is a modification or a component part of light; or whether light, as some suppose, is a component part of heat. In a popular work of this kind it would be highly improper to enter into abstruse disquisitions on such points, and we shall therefore, in

concurrence with the generality of modern chymists, speak of heat and light as substances, and as distinct and simple substances; and we must content ourselves with noticing some few instances of their connexion, without attempting to explain them. The sun is generally considered to be the common source, and the only source, both of heat and light; and it is probable, that all proceeded originally from that fountain, although the light and heat afforded by combustion, the emission of light from phosphorus, and of heat by friction, appear at first sight to be so many instances of distinct sources.

The rays of the sun seem to afford heat only when they meet with an opaque substance, and not when they pass through a transparent one, as air, or water, or when they are reflected by a white or polished one. The air is not heated immediately by the rays of the sun passing through it; but on their meeting with an opaque body, as the earth for instance, heat is elicited, and is thence gradually communicated to the surrounding atmosphere. This accounts for the intense cold of lofty mountains. If the rays of the sun warmed immediately the air, through which it passed, the air ought to have the same temperature in those regions, as in the vallies below; but it is not until the rays are obstructed by the earth, that they have the effect of communicating heat; and

therefore the further we remove from the earth's surface the greater is the degree of cold.

When the sun's rays fall upon a white or polished body, they communicate no heat; and in proportion as substances have the power of reflecting the rays, is their temperature more or less increased. An old but curious and interesting experiment may be brought in elucidation of this fact. If pieces of cloth of different colours (white, scarlet, and black, for instance) are laid at the same time on the surface of the snow, where the sun's rays can fall upon them, they will be found after some hours to have sunk into the snow to various depths, according to their reflecting powers; the white, which reflects the most light, will have sunk the least; the scarlet, reflecting less, will have sunk more; and the black, which reflects little or none, will have sunk by far the deepest into the snow.

In this experiment the rays falling on the black being absorbed, and not reflected, produce heat, which causing the snow to melt, necessarily makes that piece of cloth to sink; the others reflecting more of the rays, less heat is emitted, and consequently they sink less into the snow. It is for the same reason that black clothes of all kinds are much warmer in summer than light-coloured ones. And the same fact, we are informed by Saussure, is known to the Swiss peasants, and taken advan-



tage of by them when the snow lies too long upon the ground. He tells us, that, when this is the case, and they want particularly to sow their seeds, they are in the habit of spreading black cloths upon the surface of the snow, to facilitate its melting.

You will now easily understand, why a thermometer, that has its bulb blackened, is more sensible to an increase of heat than a common one; and why, when both are exposed to the light, the blackened one indicates a higher temperature. In this case the rays of light, that are reflected by the common thermometer, are absorbed, and emit heat in the blackened one, and consequently increase the temperature of the contained mercury.

That it is the absorption of light in this case, that causes the heat, is proved by interposing a plate of transparent glass between a thermometer and a lighted candle. The glass will evidently intercept the rays of heat, and transmit only those of light, and yet the mercury in the thermometer will rise, and particularly if the bulb of it is blackened.

The sultry heat experienced on the surface of the water in a sunny day arises from the reflection of the rays of light. The temperature of the water is but little raised, because the light is reflected, and not absorbed: but the reflected rays, as well as the direct rays of the sun striking upon

## 24 CONNEXION OF HEAT AND LIGHT.

any object, that is on the surface of the water, makes it so much the hotter to persons in that situation.

Some persons reasoning upon these facts, that light when absorbed emits heat, and that black bodies absorb whilst white-ones reflect it, have argued for the propriety of forming black walls for fruit trees; but their reasonings are insufficient without experiments to determine the point, as will appear from the following consideration. The walls themselves will no doubt be warmer than if they were white; but the heat will be communicated from the walls to the air immediately in contact, and not to the fruit, which very seldom touches the wall, and then only by a small surface; the heated air being unconfined, will most of it pass away, and thus the heat emitted by the absorption of light be of little advantage towards the ripening of the fruit. But if the walls are white, they reflect the light; and these reflected rays meeting with the opaque substance of the fruit, and other part of the trees, emit heat, that is directly applied to the desired purpose. The fruit is in this respect precisely in the same situation with a person on the surface of the water.

It is therefore necessary to determine by experiments, to what extent the temperature of the air is increased at the distance from the black wall, that the fruit usually hangs; and whether it is more



more than equivalent to the heat emitted by the absorption of rays reflected from the white wall.

In a pinery, however, or other hot-house, particularly where there is no fruit growing near the wall, I conceive that a black wall would be decidedly preferable to a white one; for here the air, heated by the warmth of the wall, not being allowed to escape, would increase the temperature of the whole air in the house; whereas the rays reflected by a white wall would many of them pass again through the glass of the windows and the roof, without adding to the warmth within.

Besides the above instances of intimate connexion between heat and light, the phenomena of combustion afford still others. When the temperature of a piece of iron is raised to the state called incandescence, that is until it becomes red hot, it emits light as well as heat; and when a more inflammable substance is heated, combustion is the consequence, during which there is a rapid extrication of light in the form of flame. The source of the light in these instances is still a matter of dispute.

Although heat and light are in so many instances very intimately connected, we have examples of the existence of the one without the other.

By friction, heat is extricated unaccompanied by light.

In phosphorus, and other bodies possessing phosphorescent qualities, as glow worms, shining fish, and putrid animal and vegetable substances, we have light without heat; at least the means have not yet been discovered of rendering the heat sensible. And again, the rays of light reflected from the moon have not yet been satisfactorily proved to emit heat.

## ESSAY IV.

### HEAT IN PARTICULAR. EXPANSION BY HEAT.

OUR observations on heat in particular will be best arranged by considering separately the general effects of heat. These are, 1st. Expansion; 2dly. A change of form, as from solid to fluid, or from fluid to vapour; and 3dly. Combustion.

*Expansion by heat.* All bodies, whether in the solid, fluid, or gaseous state, are more or less expanded in every direction by the application of heat; unless in some instances, where there seems to be a chymical change in the nature of the substance, as in the baking of clay, where there is a contraction in all dimensions, instead of expansion, which seems to arise from a semifusion, during which there is an alteration in the arrangement of the particles, approaching somewhat in its nature to the crystallization of salts.

As bodies in general expand when heated, so do they contract when cooled; but to this there is an exception in the freezing of fluids, where, in consequence of the new arrangement in their particles, there is always a considerable expansion,

The force with which water expands when in the act of congelation is immense. Muschen-

broeck, who made experiments on this subject by freezing water in metallic globes, found the force sufficient to burst one of brass, that would have required a force equal to 27700lbs. to have burst it.

It is by this means that huge fragments of rocks are separated; the water that penetrates into the fissures expanding with such force during congelation, as to break off the corners and projections.

The same circumstance is sometimes taken advantage of in splitting slate. The Collywestern slate is dug from the quarries in large blocks, these are then placed in an opposite direction to what they had in the quarry, and the rain is allowed to fall upon them; it penetrates the fissures of the slate; and the first sharp frost freezes the water, which, expanding with its usual force, splits the slate into thin layers.

The benefit that a frost is known to afford to ploughed land, is effected by the expansion of the water breaking and crumbling down the clods of earth.

The expansion of a *solid* body by heat may be instanced in iron, and other metals: If a cylinder of iron, that exactly fits a ring, so as just to pass through it, be heated until it becomes red hot, it will not then pass through the same ring; but if you immerse it in cold water, or wait till it is

gradually cooled, it will pass through the ring again with the same facility as before. This fact is taken advantage of by coopers in fastening the staves of a cask with iron hoops; they heat the iron hoops, and of course enlarge them, before they put them on, that in cooling they may contract, and tighten the cask.

In time-pieces this expansion of metals is the cause of slight errors; the vibration, or time of oscillation, of a pendulum is regulated by its length; the longer the rod the slower the vibration; in the summer, therefore, the rod being lengthened by the heat, the pendulum oscillates less quickly, and the clock goes slower than in winter; and this is the case with all clocks made in the usual way. To rectify this error, time-pieces, intended to be very accurate, are made with what is called the gridiron-pendulum, which is invented on the principle that different metals are expanded by heat in different degrees. Brass, for instance, expands twice as much, and zinc three times as much as iron by the same increase of temperature. In the gridiron-pendulum, therefore, there are two rods of different metals, connected by a cross-bar, so proportioned in length, and so disposed, that the expansion of the one shall elevate the weight in the same proportion as the expansion of the other tends to depress it; the pendulum therefore constantly remains of the same

length, and the effects of expansion or contraction in the rod are counteracted.

In the glass manufactories the expansion and contraction of glass by heating and cooling is a frequent source of inconvenience and expense. It is naturally a very fragile article, and if cooled or heated very suddenly is known to crack, and break to pieces; hence the necessity of what is called annealing, which is the exposing of new made glass to be very gradually cooled.

If heated glass is suddenly cooled, the external surface, having a tendency to contract whilst the inner parts remain in their expanded state, is necessarily ruptured in the same way that a bladder filled with air, when wet, will be cracked in drying by the exertion of its particles to contract, whilst the air within remains in the same state of expansion.

If the annealing of glass be not well performed, the particles on the surface may be contracted so much more, than those of the internal parts, as to give the glass an irregularity in its texture, but not so much so as to cause a fracture. Such glass appears sound, and is therefore saleable, but is ever after less able to bear sudden alternations of heat and cold. This is the cause why so many glass vessels crack the first time that hot water is poured into them, or that they are otherwise exposed to sudden heat. The reason why glass breaks by the too sudden application of heat is, that the particles of the



surface being more heated expand more than those of the inner parts, and in their tendency to separate produce a fracture.

Several ingenious modes of breaking glass in any required direction, such as are practised by chymists, are founded on this circumstance; by which means glass vessels that are broken may be fashioned and fitted for a variety of uses.

One mode, as pointed out by Mr. Henry, is to dip a piece of thread or string in spirits of turpentine; wrap it round the glass in the direction that you require it to be broken in, and then set fire to it. Another mode is, to draw a red hot skewer across the glass in the desired direction; and a third is, to wrap a red hot wire round the glass, and if it does not immediately crack, to throw cold water on it, whilst the wire remains hot. The two former modes depend upon the sudden expansion, and the last upon the sudden contraction of the particles on the surface of the glass.

The expansion of *fluids* by heat is much greater than that of solids. It is made very evident by heating spirits or any other fluid in a glass vessel, that has a long and narrow neck; as the heat is increased the fluid is expanded, and it consequently rises in the neck of the vessel.

This expansion of fluids has been very usefully applied in the construction of thermometers, by

which it is made the means of measuring the variations of heat in other bodies.

In the thermometer, which is an instrument so common as to need no description, the liquor contained in the tube is expanded by heat, and contracted by cold, and consequently rises and falls; which rising and falling is rendered very sensible to the eye, by making the bore of the tube, which may be compared to the neck of the vessel in the former experiment, very small in proportion to the bulb, which may be considered as the body of the vessel.

This tube being applied to a scale, formed on fixed principles, the rise and fall of the liquor within it is measured with accuracy, and thus becomes the true sign of the increase or diminution of temperature in any substance, to which the bulb of the thermometer is applied. It does not however indicate the real quantity of heat in such substances, but only shows that one body is warmer than another, and by how many degrees of heat the temperature of the one exceeds that of another.

When a thermometer is immersed in water, which causes the mercury in the tube to stand at the fiftieth degree, and then into water, which raises it to a hundred, it is a common expression to say, that the latter water is twice as hot, or contains twice as much heat as the former; and thus Sir

Isaac Newton talks of boiling water being three times as hot as the blood in the human body.

This however is an error, and it arises from the idea, that the scale of the thermometer commences at the point, below which there is no heat. Thus Newton believed the freezing point to be the natural zero, below which there was no heat; whereas we now know, that the freezing point is several degrees above the temperature of the air at certain seasons in the polar regions, as in Hudson's Bay, or at Kamtschatka. In the latter place mercury has frozen by exposure to the natural cold, so that the air at such time must have been at least  $40^{\circ}$  below the zero of Fahrenheit's scale, or  $72^{\circ}$  below the freezing point.

By artificial means still more intense cold than this has been produced, and yet we have no reason to believe that we have reached the lowest point, or that of the privation of all heat.

The range of heat from its lowest to its highest degree may be aptly compared to an immense chain, formed of links, that have exactly the same length, the extremities of which chain are beyond the limits of our sight. The most distant link, that we can distinguish towards one extremity, we mark as the first, that next to it the second, and so on, till we come to the most distant that we can distinguish towards the other extremity. Now in speaking of the links of this chain, which may be compared to

the degrees of heat on the scale of a thermometer, it would evidently be erroneous, to say, that an object placed at the hundredth link was twice as far from the extremity, as one placed at the fiftieth; nor could we say how far either was from the extremity; but knowing that there are fifty links between the two, we can form an idea of their distance from each other, and their relative situation with respect to other objects placed along the same chain, that are within our view.

So, with respect to the thermometer, we know the number of degrees between the temperature of boiling water and of ice; and that the former, which is at  $212^{\circ}$ , is as much hotter than water at  $122^{\circ}$ , as this is hotter than ice, which is, at  $32^{\circ}$ , there being  $90^{\circ}$  between each. Thus then the thermometer teaches us the relative, but not the absolute heat of bodies.

The tube of the thermometer is sometimes filled with air, sometimes with spirits, and sometimes with mercury. The air thermometers, being most delicate, are used in some chymical experiments; as the air is expanded or contracted in these thermometers, a coloured liquor is made to fall or rise, which marks the degree of expansion, and consequently the variation of temperature.

The spirit-thermometers are applicable to intense degrees of cold, because the spirit will not freeze where the mercury would; but they will not answer

for such high degrees of heat, the spirit being sooner evaporated. For ordinary use and for most chymical experiments the mercurial thermometers are to be preferred, and principally for this reason, that mercury is equably affected by equal increments of heat at different temperatures, which is not the case with spirits, and still less so with air.

Thermometers, from their construction, are not calculated to measure very high degrees of heat; the tubes would be broken, and the mercury would be volatilized, if they were exposed to much heat. To answer this purpose other contrivances have been offered. Some thought that the expansion of metals would furnish a convenient measure, others proposed the rate at which metals cool, as a measure of their former temperature; but none can be compared in accuracy to the pyrometer invented by Mr. Wedgwood.

Noticing the contraction of clay in baking, he found that it contracts uniformly according to the degree of heat; and if the same kind of clay is used, that its contraction becomes an accurate measure of the temperature.

His pyrometer consists of a number of small pieces of slightly baked clay, and a brass plate with two rulers, so fixed to it, that they gradually approach each other. On this plate is a scale of degrees, made to correspond with those of Fahrenheit's. The first degree of the pyrometer corresponding



with  $1077\frac{1}{2}^{\circ}$  of Fahrenheit's, and each degree afterwards equalling  $130^{\circ}$  of Fahrenheit's. The pieces of clay are all of a size, and fit in, between the rulers, where the first degree is marked.

When this instrument is used, one of the pieces is exposed to the heat required to be ascertained, that of a furnace for instance; and when it has been exposed long enough to have acquired the heat of the furnace, it is withdrawn, cooled, and then applied to the rulers, between which it is allowed to slide as far as its bulk will admit it. The degree marked at the place, where it stops, indicates the temperature of the furnace; for the greater that has been, the more will the clay be contracted, and consequently the further it will slide between the converging rulers.

Before we quit the subject of expansion of fluids by heat, we must notice the peculiarity of water in this respect. Within a certain range of temperature water follows the general law of being expanded by heat, and contracted by cold; but beyond this, it is affected in the opposite way. When heat is applied to water at  $32^{\circ}$  it gradually contracts till it arrives at  $40^{\circ}$ , whereas other bodies expand in the same situation; but after it arrives at  $40^{\circ}$ , it follows the general law, and is dilated by the further application of it. When boiling water is gradually cooled, it regularly contracts, until it arrives again



at  $40^{\circ}$ , and then it shows its peculiarity, and is expanded as it is further cooled.

The final cause of this peculiarity is to prevent the sudden congelation of large masses of water, and to preserve a warmth in some part of the water of lakes, and rivers, that may support the life of its various inhabitants. How it effects this, is thus explained.

Water never freezes until its temperature is reduced to  $32^{\circ}$ . When the particles of water are expanded or contracted by variations in their temperature, they become specifically lighter or heavier than the surrounding particles, and consequently rise in the former and sink in the latter case. When therefore the water of a lake, which is at  $60^{\circ}$ , is gradually cooled by the approach of winter, the particles on its surface, being first cooled, contract, become specifically heavier, and therefore sink. Their places are supplied by others, which are cooled, contracted, and sink in the same way; and thus the whole body of water is gradually cooled. This process would continue, were it not for the peculiarity we have been speaking of, till the whole body of water had been sunk to the temperature of  $32^{\circ}$ , and then the whole would be suddenly frozen; which would prove certain destruction to all the animals it contained.

This would be the case, did water expand and contract by heat like other fluids; but now, as soon

as the water of the lake is all cooled to  $40^{\circ}$ , the particles on the surface no longer contract, but on the contrary expand; they are consequently lighter than the particles below, and therefore remain at top, and are still further cooled till they come to  $32^{\circ}$ , and then ice begins to form.

Ice being but a bad conductor of heat, the process of cooling now goes on very slowly in the water; and whilst the air and ice are cooled, perhaps far below  $32^{\circ}$ , the water under the ice remains even at  $40^{\circ}$ , or little below.

This wise provision of nature, which answers such an important end, is confined to fresh water. That of the ocean being prevented from freezing, except in the polar regions, by its immensity, its communication with waters of warmer climes, and by its containing salt, which enables it to be reduced below  $32^{\circ}$  without freezing, needs not this peculiarity of expanding after its temperature is reduced to  $40^{\circ}$ . The water of the ocean therefore expands and contracts according to the general law, and this again is attended with considerable advantages.

It being necessary that the whole body of water should be equally reduced in temperature, that on the surface is seldom cooled so low as  $32^{\circ}$ , and is therefore, in the winter time, warmer than the atmosphere, to which it becomes a constant source of heat. The winds in passing over the ocean acquire warmth, and moderate the cold of the atmos-

phere on the land to which they blow; and this is the reason why islands are more temperate than parts of the continent situated in the same latitude.

The expansion of *gasses*, airs, or gaseous fluids, by heat, may be instanced in the simple experiment of holding a half-blown bladder before the fire. As the air in the bladder becomes heated, it expands, and what before only half filled it, now distends it to the utmost. It is by this expansion of air by heat, that heated bodies are enabled so readily to part with their heat to surrounding objects, and that so just an equilibrium is maintained.

When any part of the air is heated by the sun's rays on the earth, or by any heated body, it becomes expanded, and of course ascends, whilst other particles of air rush in to supply its place. Thus heat is transmitted from one place to another, and becomes more equally diffused.

This is one cause and the principal cause of winds. When the atmosphere in any particular country is heated, as in the torrid zone, the expanded air ascends, and currents of cooler air rush in on all sides to supply its place. These currents form the monsoons and trade winds, which blow regularly in certain latitudes, and at stated times. The draughts of air perceived in rooms, where there are fires, are currents of air rushing in to supply the place of the expanded air, that passes up the chimnies. It is by facilitating the egress of

the heated air, that rooms are properly ventilated; and by contriving means to prevent its escape, that stoves and hot-houses are able to preserve their increased temperatures.

## ESSAY V.

### EFFECT OF HEAT IN CONVERTING SOLIDS INTO FLUIDS, AND FLUIDS INTO VAPOUR.

WE now come to the second general effect of heat; its power of changing the form of bodies by converting solids into fluids, and fluids into vapour.

Most substances are capable of being thus melted, and vaporised by the application of heat; and most probably all would be so, were we able to excite a sufficient degree of heat. By abstracting the heat, we again reduce most vapours to their fluid state, and fluids to that of solids. And it is likewise probable, that such as at present we cannot condense, or freeze, would be subject to these changes, were we able to excite a sufficient degree of cold.

It is only when the temperature is raised to a certain degree, that solids begin to melt, or fluids to be vaporised; and this degree is different for every different substance, but is always precisely the same for the same substance, provided other circumstances are similar. Thus ice always melts when heated above  $32^{\circ}$ , as water always freezes when cooled below  $32^{\circ}$ ; and water is always con-

verted into vapour when its temperature is raised to  $212^{\circ}$ , provided the pressure of the atmosphere is the same.

Wax has another degree at which it is melted, lead another, silver another, and gold another. The degree of heat, at which spirits boil, or begin to be converted into vapour, which is the same thing, is lower than the boiling point of water; and that, at which ether boils, is a great deal lower still.

The point, at which salt water freezes, is lower than the freezing point of fresh water; and in the act of congelation its salt is deposited; and the ice, if separated and melted, affords fresh water. Some of our navigators have observed this fact with great joy, and obtained a supply of fresh water, where they but little expected to meet with it. The mountains of ice met with at sea in the polar regions are wholly of fresh water, and pools or basins of fresh water are often found on them from the partial melting of the ice.

Although all these substances have their fixed points, at which they boil under similar circumstances, yet the pressure of the atmosphere has a very considerable influence in determining the point. The greater the pressure the greater the degree of heat requisite for making the liquor boil; and the more we can diminish the pressure of the atmosphere, as is done by the airpump, the less is



the degree of heat that is required to convert it into vapour.

In this way æther, spirits, and even water, are made to boil at the usual temperature of the air, when the pressure of the atmosphere is removed by means of the airpump. So much is the boiling facilitated by this means, that philosophers have gone so far as to assert, that, if all pressure was removed from the earth, every substance, solid as well as fluid, would immediately be volatilized, or converted into vapour.

For further observations on this point we shall confine ourselves to the consideration of water, as its influence on this substance is most attended to. Water, upon an average, is found to boil at  $212^{\circ}$ , and this is generally considered its boiling point; but in this country there is a considerable difference at different times in the weight of the atmosphere. In the barometer, which is the instrument for measuring this pressure, the height of the mercury varies as much as three inches, and a rise of one inch makes the water require two degrees more of heat to boil it. There is therefore in this country a variation of six degrees of heat in the temperature of boiling water at different times. When the barometer is at the lowest, water will boil at  $209^{\circ}$ ; and when it is at the highest, it will not boil till it is heated to  $215^{\circ}$ .

The more elevated the situation, the less is the

pressure of the air, and consequently water will boil with less heat on the top of a mountain, than in the valley.

An amusing experiment, easy to be performed, which I shall now describe, shows this effect of pressure on the boiling of water, as well as any experiments that can be performed with the air-pump. Half fill a Florence flask, or other glass vessel, with boiling water, and cork it tightly. The water is now at rest; but pour a little cold water on the upper part of the flask, and it will begin to boil; then pour hot water upon it, and it will cease; pour the cold water again, and it will boil; and so on, for a considerable time.

The explanation of the experiment is this. When you cork the flask, the upper part of it is filled with vapour from the boiling water, and the cold water poured upon this part condenses the vapour. Now as the air cannot get in, there is a partial vacuum; that is, the pressure of air on the surface of the water is considerably diminished. This being the case, the water will boil at a lower temperature; and the heat, which it retains, is sufficient for the purpose. In the next place, by pouring hot water upon it, that within is partly again converted into vapour, which affords the same pressure as the air would do; the water therefore ceases to boil, because its heat is insufficient under that pressure to make it boil.

It has been said, that, by increasing the pressure on the surface of water, you retard its boiling. It is on this principle, that what are called *digesters*, are formed. By means of screws, the top of the vessel is kept down with such force, as to prevent the escape of the vapour, which increasing the pressure on the surface of the water, in the same degree enables it to acquire a higher temperature. Papin carried his to that pitch, that the water acquired a sufficient degree of heat to melt lead.

A vessel on the same construction, but of far less power, is now introduced into the kitchen with economical views. By enabling the water to be heated much above the boiling point, its solvent powers are increased; and thus bones are made to afford their glutinous and nutritious parts to the water, that common boiling would not be able to extract.

The immense power that is exerted by water, on the point of being converted into steam, requires digesters, and other instruments, intended to confine it, to be made with great care, and with amazing strength.

By a sufficient increase of heat it may be made to exert almost any force. It has been made to burst cannons, and still stronger machines; and by the important invention of the steam engine, it is brought to move very heavy weights.

When a substance undergoes the change that we have here been talking of; from solid to fluid, or fluid to vapour, it is not only necessary to raise its temperature to the melting or boiling point, but to supply it with still more heat, for the conversion is attended with an absorption of heat.

When ice is melted it absorbs heat from all surrounding bodies, which heat has not the effect of increasing its temperature, but becomes latent; the water is not hotter to the feeling, or to the thermometer, than the ice was, before it was melted, but it has absorbed and contains more heat.

The same happens, when a fluid is converted into vapour; and the same quantity of heat, that is thus absorbed, is again extricated, when the vapour is condensed into a fluid, or the fluid frozen into a solid.

The application of this fact assists us in explaining a variety of phenomena, that without the knowledge of it would be inexplicable. Put a vessel of snow or of ice before a fire, and although it is all the time receiving heat from the fire, a thermometer immersed in it shows no increase of temperature; all the heat, that is received, being necessary to convert the snow into water: but as soon as it is all melted, the thermometer begins to rise.

Were it not for this circumstance, all the snow and ice would be instantly melted; when the tem-

perature of the air is raised above  $32^{\circ}$ , the consequence of which would be dreadful inundations after every winter.

So much heat is absorbed when a solid becomes fluid, that if we can suddenly effect the conversion, we produce a great degree of cold, and on this depend the effects of freezing mixtures. When snow and salt mixed are melted in a warm room, so much heat is absorbed by them that a vessel of water immersed in the mixture becomes frozen, notwithstanding the warmth of the room. In this way our confectioners prepare different kinds of ices in the summer. Various mixtures of salts, when dissolved in water, produce the same effect without the addition of ice. Eleven parts of sal ammoniac, ten of saltpetre, and sixteen of Glauber's salt, mixed with thirty-two parts of water, will produce a cold sufficient to freeze water. By dissolving muriate of lime in nitrous acid even mercury may be frozen.

The heat that is given out, when water is frozen, tends to inoderate the intensity of our winters, and accounts for the increase of warmth that is frequently observable after a fall of snow. Other fluids give out heat during their conversion to a solid state. In salts it may be instanced by the following experiment. Boil a pound of Glauber's salt in a pint of water, and when boiling hot, pour some of this saturated solution into a phial, but



not so much as to fill it ; cork the phial close, and let it stand to cool. When cold, the solution is still fluid ; but the instant you draw the cork, the salt becomes crystallized, and the whole mass solid, and at the same time so much heat is evolved, as to make the phial very sensibly warm. This is an instance of heat being given out by a body during its conversion from a fluid to a solid state.

The explanation of the experiment is this : water will dissolve more Glauber's salt when hot than when cold ; and cold water will dissolve more in proportion as the pressure of the atmosphere is diminished. The hot water was here saturated, and would, if suffered to cool in an open vessel, have deposited part of the salt ; but by corking it when hot, the superior part of the phial being filled with vapour, would form a partial vacuum on the surface of the solution, when by cooling the steam was condensed. The pressure of the atmosphere being thus diminished, the cold water was able to retain in solution all the salt that the hot water had dissolved ; but as soon as by drawing the cork you admitted the usual pressure of the atmosphere, the cold water was rendered incapable of holding so much salt in solution, and part was instantly crystallized.

When fluids are converted into vapour, I have said, that there is much heat absorbed, and of course cold produced. This takes place both when they are vaporised by heat, and when they are raised



by what is called spontaneous evaporation; which process differs from the former in other respects, though it agrees in this.

When æther, spirits, or water are exposed to the air, they are gradually evaporated, and in this process absorb heat, as well as when they are made to boil and are thus vaporized. To prove this, dip the bulb of a thermometer in æther, and expose it to the air, and you will find the mercury to fall considerably; or dip your hand into the same liquor, or into spirits, or even water, and then expose it to the air, and you will feel a very considerable degree of cold, in consequence of its absorbing heat from your hand to convert it into vapour.

In warm climates the inhabitants cool their water, and other liquors for drinking, by wrapping the vessels in wet rags, and suspending them in a current of air; or by keeping their water in porous earthen vessels, through which a part gradually oozing is evaporated, and cools the rest.

It is this evaporation that makes a person feel so cold when his clothes are wet, although he is perhaps sitting near a fire; and it is the cold thus produced that injures the health much more than being exposed to a cold and sharp air. It is the absorption of heat by the vapour that prevents water from acquiring a greater degree of heat than  $212^{\circ}$ . If you boil water ever so violently, or apply to it ever so intense a heat, it never increases in temperature;

the heat that you communicate all going to the conversion of it into vapour. In cooking therefore it is useless to apply additional heat to water that is boiling, to make it, as the servants call it, boil fast. If you keep the water boiling at all, that is sufficient; and in many cases indeed articles will be as well done, and as soon done, by a heat considerably less than that of boiling.

Having observed that vapours contain more heat than fluids, and fluids than solids, when their temperature is the same, I must now add, that among fluids, among solids, or among vapours, one kind contains more heat than another; thus a pound of water contains more heat than a pound of mercury; a pound of iron more than a pound of tin; and a cubic foot of common air more than the same quantity of inflammable air.

According to the proportion that different bodies possess, such we say is their *capacity for heat*; thus we say that water has a greater capacity for heat than mercury, and iron than tin. The consequence of this difference of capacity is, that different bodies exposed to the same heat require different times to be raised an equal number of degrees; thus, expose the same quantity of mercury and of water to the same heat, and the former will be heated  $8^{\circ}$ ,  $10^{\circ}$ , or  $12^{\circ}$ , long before the water, because it requires a less quantity of heat to raise it.

In chymical experiments, whenever there is a change of capacity without a change of temperature, there is sure to be a sudden evolution of heat, or absorption of it producing cold. Thus on mixing spirits and water, and still more on mixing vitriolic acid and water, a very sensible degree of heat is evolved, because the mixture has less capacity for heat, than the two separately. So the heat produced when fluids become solid, and the cold when they become vapours, as mentioned above, is explained by the solid having a less and the vapour a greater capacity for heat than the fluid.

All the heat afforded by combustion of inflammable bodies is given out, in consequence of the result of combustion, as the ashes, smoke, &c., having a less capacity for heat, than the combustible body, and the air that has been consumed.

There is another law of heat that requires to be mentioned, viz. that it passes more readily through one substance than another; and this quality in the substance to transmit it, is termed its *conducting power*. If you hold a glass tube and a piece of wire with your hand in the flame of a candle, you will soon be made sensible that the wire is the best conductor. Air, when confined, is a bad conductor; and this is the reason why all porous bodies are so.

Wool, by admitting and confining particles of air in its interstices, is a very warm covering for the

animals that bear it, and a warm clothing for man.

Double windows and double walls make the warmest rooms in cold climates, and the coolest in warm climates; for the air enclosed between them, being a worse conductor than either wood or stone, prevents the egress of heat in the cold, and its ingress in the warm climates. For the same reason partitions made with lath and plaster, with an intermediate space, make the rooms in this climate warmer than wainscot partitions.

In hot-houses not only the walls but the sashes should be double; to retain the heat most effectually.

Snow being a light porous body is a bad conductor of heat, and on this account is of infinite service in preserving vegetation; for let the air be ever so cold, the ground, that is covered with snow, is seldom reduced in heat below  $32^{\circ}$ ; and this accounts for animals living so long, that are buried in the snow.

## ESSAY VI.

## COMBUSTION.

THE third and last general effect of heat is *combustion*. When a body, that is not very inflammable, is heated to a certain degree, it becomes luminous, as iron for instance, and is then said to be ignited, or to be in a state of incandescence; but when a more inflammable substance is heated, it undergoes a process called inflammation, during which heat and light in a greater proportion are emitted, and the chymical qualities, both of the inflammable body and of the surrounding air, are materially altered.

Incandescence is probably the same process with inflammation, only in a slighter degree, and we shall consider both under the term combustion.

The combustible body in common language is said to be consumed; but it must not be supposed that it is annihilated, that it is absolutely destroyed, for in fact it is only changed; and the results of combustion are always equal in weight to the inflammable body, and the air absorbed.

It ought here to be observed, that inflammation or combustion can never take place without air.



If an ounce of phosphorus is confined in a vessel of air, and the whole apparatus weighed, and if you then set fire to the phosphorus, and let it burn until it is, to speak in common language, all consumed, the apparatus, on being again weighed, will be found to have neither lost nor gained by the experiment. A change however has taken place, the volume of air is diminished, and the phosphorus is converted into an acid; which acid, if weighed, will be found equal to the phosphorus that has been burnt, and the air that has disappeared.

Similar facts will be ascertained in every instance of combustion. There is a chymical change, but no absolute loss or consumption. If the whole products were collected after a candle is burnt out, or after the combustion of any kind of fuel, they would always be found to equal in weight the inflammable body and the air, that seem to have been consumed.

As the presence of air is an essential requisite in every case of combustion, and as it always undergoes a chymical change, it is probable that it is the source both of the heat and light that are extricated. Of the heat indeed we know it to be the chief, if not the only source, in consequence of the change of capacity that attends its chymical change. The vulgar opinion, therefore, that the fuel gives out the heat, and the candle the light, is erroneous; and it is an inaccuracy in language to

say, that one kind of fuel gives out more heat, or one kind of candle more light, than another. As, however, the error and the inaccuracy can be the cause of no inconvenience, it would at least be useless in common conversation to make use of other terms.

As air is thus necessary to combustion, great attention to procure a sufficient supply becomes a point of considerable consequence in promoting and keeping up the process. In constructing furnaces, and even in fitting up fire-places, it requires the chief consideration. In the former, the length of the chimney in a great measure influences the heat, by causing a greater or smaller current of air through the fire; and dampers or registers are in some cases used, which, by admitting more or less air into the furnace, regulate the intensity of the heat. The use of bellows depends on their supplying a greater quantity of air; and in the furnaces of iron-foundries immensely large bellows are used to increase the draught.

In common fire-places, the dimensions of the chimney, the position of the stove, and the free accession of air, are the three points chiefly to be attended to, with a view of having good fires, and preventing the inconvenience of smoky chimnies.

When the chimney is very large, as most kitchen chimnies were formerly built, they are

almost sure to smoke. The column of air in the chimney not being all sufficiently heated to ascend, there are different currents; the heated air ascends in the middle, whilst the colder air descends at the sides, and in descending forces part of the smoke with it into the room.

To prevent this, the fire is made larger, and the door, or a window, is opened; the heat now is sufficient to expand all the air in the chimney; but if the door or window is not open, there not being a sufficient quantity of air admitted by the usual crevices, the external air forces itself down the sides of the chimney to supply the place of that which is consumed, and that, which being expanded, passes up the middle of the chimney, and thus the same inconvenience is repeated. By contracting the throat of such a chimney, the column of air to be heated is less, and is sufficiently expanded by less fuel, at the same time that the current of air required to keep up a brisk fire, is less; so that the chimney will no longer smoke, nor does the necessity of opening the door exist.

If a stove is placed very forward in the room, the heated air is expanded, and ascends in the apartment, and the smoke along with it, particularly when the fire is first lighted; the air in the chimney being then not heated so as to establish a current. This is often observed in old-fashioned

moveable fire-grates, and is generally remedied by pushing them a little backward.

The free access of air is the most important consideration. We have seen, that without it a current of air will be formed down the chimney that must inevitably bring the smoke with it. In small and close rooms it is the most frequent cause of smoky chimnies and bad fires. When it is found, that opening a door or window prevents the smoke from descending, the cause is evident, and the cure is generally accomplished by contriving a communication with the air; and if this can be done under the grate, or near it, so much the better; as a current of cold air from a distant part of the room will be sure to prove inconvenient. If the room is lofty, a communication may be made over the door or near a window, above the height of persons in the room, which will prevent any inconvenience from the current. But in low rooms, I have seen this attempted and fail; or it has answered only when the fire is first lighted, or before the air in the room has been heated by company.

The reason of this becomes clear and evident, if a candle is held before the opening, at a time when the air in the room is heated; for the flame of the candle is drawn towards the opening, and not from it into the room; which proves clearly

that, instead of admitting air, it is the channel through which air is carried out of the room.

Many chimnies only smoke when the fire is first lighted, which arises from the air in the chimney being colder than the external air; in consequence of which it descends, and, passing through the fire, carries the smoke with it through the bars into the room.

This may be prevented by laying the fire very light, and setting fire to a handful of shavings on the top previously to lighting the fire at the bottom; or more certainly by setting fire to a piece of paper, and holding it a little way up the chimney. This heating the air in the chimney is sure to establish a current in the proper direction, and carry the smoke upwards.

Most chimnies are in this predicament when fires are lighted for the first time after a long interval, as in the beginning of winter; and ignorant people attribute it to the air in the chimnies being damp. The fact is, that the air in the house, and consequently that in the chimney, is colder than the external air, as is the case during summer and autumn, until by lighting fires we have increased its temperature. The first time a fire is lighted, therefore, as the air in the grate is expanded, its place is supplied by cold air from the chimney, which rushing through the fire carries the smoke into the room, unless, as I have before advised,



some means are taken first to warm and rarefy the air in the chimney.

Argand's lamp burns better than a common one because it admits a current of air through the centre of the wick. This causes so complete a combustion, that the smoke, which oil usually gives out, is burnt in this lamp, and therefore it affords more light.

When we wish for light rather than heat, we employ such inflammable substances as allow their particles to be volatilized, as spirits or oils; for flame is part of the inflammable substance volatilized by heat, and still in a state of combustion. It is always conical, and its external surface only is in an ignited state, as is easily proved by suddenly thrusting a match into the centre of the cone, as of that arising from spirits burning in a shallow dish. If you allow it to remain there some time, and then suddenly withdraw it, the brimstone on the end of it will not be burnt. The reason why only the surface is in combustion is, that the contact of air is necessary, and it has no access to the centre.

We have now gone through the consideration of the general effects of heat, and taken notice of its laws respecting inanimate matter. It is by attending to all these properties that so much has of late been done towards economising fuel; and

Count Rumford is the person to whom we are indebted for most of these improvements.

That patriotic and humane philosopher has shown the true value of literary acquirements, and taught us the just application of philosophical truths, by making them subservient to the relief of the poor, and to the benefit of his country.

In cooking he has taught us to economise our fuel, by applying separate fires to the pots or boilers, to the ovens and roasters, and to smaller utensils, as kettles and saucepans.

In a kitchen range, as commonly fitted up, nine tenths of the heat is either carried up the chimney, or uselessly thrown into the kitchen, to the great inconvenience of the cook. If all this heat, that is lost, could be saved, or applied to the intended purposes, one tenth of the fuel, that is now expended, would be found sufficient, and consequently the saving would be immense.

The improvements, which I am about to notice, do not lay claim to so much as this, but have certainly accomplished much. The chief object is to confine, as much as possible, the heat emitted to the use for which it is intended, namely, boiling, roasting, stewing, &c.; which is only to be done by using close stoves, and applying the fire separately to different vessels. It will be unnecessary to detail minutely all the methods he has adopted to effect

this purpose. The leading principles of his improvements will be made evident by the following observations.

When in the common mode of cooking, where the kitchen is furnished with a range, you wish either to roast or boil a joint of meat, it is requisite that the fire should be made up, as the cook terms it, long before he can lay down the meat or put on the boiler. That is to say, in fact, that it is necessary to heap on an immense quantity of coals, and suffer them to burn till the fire is clear and bright, before the heat can be applied to the required purpose; and even then it is but a small proportion of the heat given out, that you can apply either to boil the water in the pot, or roast the joint upon the spit.

If you are boiling, for example, all the heat that emanates from the burning fuel in front of the fire is completely lost; and only that, which rises from the top, and directly strikes against the pot or boiler, goes to answer the intended purpose, which cannot upon an average be so much as one tenth part of the whole heat afforded by the combustion of the fuel.

This mode of boiling upon an open fire, too, makes it necessary to have the kitchen ranges very deep from front to back, which adds considerably to the consumption of fuel.

In the next place, when it is required to roast

at one of these fires, all the heat that emanates from the top of the fire is decidedly lost; and of that which comes from the burning fuel in front, only such a part, as is directly opposite to the meat to be roasted, is appropriated to the intended purpose.

In most kitchens, a smoke-jack, and in many an iron oven, fitted up by the side of the range, and heated by means of a flue going from the back of it to the oven, are part of the cooking apparatus. The plausibility of the jack being made to act, and the oven to be heated, without an additional fire, has persuaded most people to believe them very economical contrivances; whereas, if duly considered, they will prove to be very extravagant ones, adding considerably to the expenditure of fuel.

To erect one of these smoke-jacks, it is necessary that the chimney be very large; and to put it in motion, it is requisite that the whole column of air contained and passing through this large chimney be constantly heated, not only sufficiently so to carry up the smoke, but to produce such a current as will keep this badly-contrived machine in motion.

To effect all this, a much larger fire must be made, than would be required merely to roast the meat, particularly if it is a small joint; for if the fire be reduced, the smoke-jack stands still.

Besides this unnecessary exhaustion of fuel, almost every fireplace thus constructed is found to

smoke, unless the door or windows be kept open, and a brisk fire kept up; so that such apartments cannot be preserved uniformly warm.

To heat the iron oven, that I have spoken of, it is requisite that a very brisk fire be kept up in the grate; and from the length and awkward structure of the flue, in such as I have seen, the greatest part of the heat is lost and dissipated, before it reaches the oven.

Another mode of applying heat to cooking, which is thought by some a very great improvement, is by means of what is called a steam-kitchen. This apparatus is very neat, and adds much to the convenience of the kitchen, as it is not necessary to over-heat it by a large fire, as in the common mode of boiling. This plan, however, is found by no means to save so much fuel, as was at first apprehended; and when we consider how much apparatus is to be heated by the steam, before it is applied to the desired purpose, and still more, when we consider how much heat is absorbed, and rendered inert, as it were, in the conversion of water into steam, we shall be aware of the great sources of the loss of heat in this apparatus.

Having thus pointed out how, and why, the usual modes of cooking are attended with considerable waste of fuel, it will, from what has been said, immediately occur to you, that by using separate small fires under the boilers, ovens, &c., most of



the sources of this loss of heat will be avoided. If the coppers and boilers are well hung, and the ovens or roasters well set up, almost all the heat afforded by the combustion of the fuel is applied to them; and, in consequence of the length of the flue, the current of air through the fire is so brisk, as to consume cinder-ashes moistened, or other fuel, that would hardly burn at all in open fire-places. The same quantity of food may thus be cooked with not more than one fourth part as much fuel, as in the common way.

As the machine called a roaster, a late invention of Count Rumford's, is not yet become a part of the cooking apparatus, I shall offer a slight description of it.—It is something like the common iron oven, except that, instead of being square, it is nearly cylindrical, flattened however at the bottom. It has a double door, with an intervening space of about an inch, to prevent the escape and loss of heat. There are two iron tubes running along its bottom, on the outer side, which turn up at the back of the machine, and open into it, near the top; the other orifices open into the kitchen, in front of the roaster, and immediately under it; which orifices are furnished with plugs or stoppers. Another part of the apparatus is a valve, shutting or opening a communication between the roaster and the chimney of the flue. The grate, which should be very small, to prevent too large a fire

being kept up, is situated immediately under the machine, and not more than six inches below the tubes; which, with the bottom and sides of the roaster, are directly exposed to the fire. When used, the meat is to be put upon a wire stand, over a pan of salt and water, and placed either on the bottom of the roaster, or on a shelf, which most of them are made with, to allow of roasting two dishes at a time. The valve is now to be turned, so as to prevent any communication between the roaster and the chimney; and the orifices of the tubes are to be closed with their stoppers. The fire being lighted, the water in the pan is soon converted into vapour, and the meat is, as it were, parboiled. About twenty minutes, or half an hour before you expect the meat to be sufficiently cooked, the valve is to be opened, to let out the vapour; and the stoppers are to be taken from the tubes, that through them the roaster may be supplied with hot and dry air. The meat now begins to be browned, and to assume the appearance of roasted meat; from which, when quite done, it can scarcely be distinguished by the nicest palate. It has not the peculiar flavour of baked meat, and for the plain reason, that the steam of the water prevents any vapour rising from the meat in the former part of the process, and the opening by the valve prevents its remaining in during the latter part; from the confinement of which,

in the common mode of baking, I conceive the peculiar flavour of baked meat to arise.

By putting the meat into the roaster before the fire is lighted, it becomes gradually heated, and hence retains all its juices; which makes the meat cooked in this manner particularly palatable. Indeed, on this point, the Count observes, that the smaller the fire, and the more slowly the meat is cooked, the better flavoured is it when done; and what is of considerable importance, the less fuel becomes necessary. If the fire is so small, that a joint of meat requires six or eight hours cooking, less fuel will be consumed, than if the heat is sufficient to cook it in two or three hours, and at the same time the meat will be more palatable.

The roaster likewise answers all the purposes of an oven, by heating it before the bread or other things are put in, and by keeping the valve shut, and the tubes always open.

They may be made of any size, but two smaller ones are preferable to one large one. For a moderate-sized private family they are made large enough to roast a joint of meat and a couple of fowls at the same time. It should be fitted up on one side of the fireplace; and a boiler, or, if it is necessary, two, on the other side, with their steamers for vegetables, and an opening or two for saucepans and stewpans. The firegrate in the middle, being only intended to warm the apartment, need

be but a very small one. And the whole appearance of a kitchen thus fitted up is very neat, and much more comfortable, as a dwelling apartment for the servants, never being overheated, and the chimney never smoking.

## ESSAY VII.

### THE DIFFERENT SOURCES OF HEAT.

BESIDES the combustion of inflammable substances, we have other means of exciting heat. The friction of two hard bodies, one against the other, excites heat sufficient to set fire to combustibles. Instances have occurred of forests being burned down, in consequence of the wind producing such considerable friction between their boughs, as to set fire to them.

In the whale fishery the precaution is necessary, of wetting the line, and the part of the boat, that it is drawn over, as soon as the whale struck with the harpoon dives, and carries with it the vast length of the line. Otherwise the friction of the line drawn with such velocity over the edge of the boat, would unavoidably set it on fire. Carriages by the friction of the wheel upon the axle, mills, and other machines by friction of their different parts, have frequently been set on fire, and destroyed.

In the islands of the South Sea, in Africa, and in America, the natives have various means of exciting heat by friction, to light their fires. Some rub flat pieces of wood together. Others fit the end of a stick, previously charred, in a hole made



in a piece of wood, that is fastened to the ground, and then twirl the stick with celerity till it inflames. Tinder is sometimes put into the hole, or brimstone rubbed on the stick to make it take fire more readily.

Heat is likewise excited by concussion. Iron by repeated blows with a hammer may be made hot enough to set fire to inflammable substances, as is usually practised by blacksmiths.

By *collision* we excite heat, when we strike a light with flint and steel. A small part of the steel is detached, which is so much heated, as to be fused, and sufficiently so, to inflame the tinder.

The heat emitted by a change in the chymical composition of a body, accompanied by a diminution in its capacity for heat, has been already noticed in some instances. Indeed combustion is a change of this kind; but there are some other instances worth mentioning, and particularly some examples of spontaneous inflammation.

Inflammation has been known to take place from linseed oil getting accidentally amongst hemp, or hempen cloth, which has been consumed in consequence. Some particular chymical change was here effected, accompanied with a change of capacity for heat, in consequence of which so much heat was extricated, as to set fire to the materials. The same has happened with wool, and with lamp-black, when mixed with linseed oil.

When aqua fortis is poured upon any of the volatile oils, particularly if it has been previously mixed with one fifth of vitriolic or sulphuric acid, the mixture bursts out with a violent flame; owing to the same cause, *viz.* a diminution in the capacity of the substances for heat.

During every kind of fermentation, heat is evolved; thus, when green undried vegetable substances are heaped together, they begin to ferment, and often emit so much heat, as to take fire, as in haystacks made up before the hay is sufficiently dry.

There are certain chymical compositions, that possess this property of spontaneous inflammation, and they are for this reason called *pyrophori*. The pyrophorus of Homberg which instantly takes fire, when exposed to the air, is thus prepared.

Melt equal parts of powdered alum and brown sugar over a fire, and keep stirring them, till reduced to dryness. Then introduce the mixture into a common phial coated with clay, and to which a glass tube, open at each end, is luted. Keep the phial in a red heat surrounded with sand, till no more gas escapes by the tube; then close the tube with a little moist clay, to prevent the access of the air, and remove the phial from the fire. The gas that issues from the tube may be inflamed by holding to it a piece of lighted paper, and when the flame disappears, the operation is known to be completed.

A pyrophorus is said to be immediately formed, by rubbing together in a mortar fifty-four grains of sulphur, thirty-six of very dry willow charcoal, and three of phosphorus.

We shall now conclude the subject of heat by observing, that the term is often used to signify a sensation, of which the presence of caloric, or matter of heat, is the cause. Many are apt to imagine that this sensation is a sufficiently accurate test of the temperature, or degree of heat of the air, and other bodies. Hence nothing is more common than to observe, that this is very hot; or that very cold; that this is warmer than that; or that the air is colder to day, than it was yesterday; whereas we only mean to say, that to our sensations, or feeling, such and such is the case; but how far this is from accuracy in most cases, will appear from the following observations.

It frequently happens, that one person complains of the coldness of the air, at a time, when another is observing that it is warm, which is owing to their senses being differently affected. But the same person too feels very differently at different times. If he comes out of a cold sharp air into a moderately warm room, he feels it sufficiently warm and comfortable; but when he comes out of a still hotter room into the same apartment, he complains much of the coldness of it. This proves the inaccuracy with which we judge of heat by our sensations; and

you may satisfy yourself of the same point by the following experiment.

Put your right hand into a basin of water, as hot as you can well bear it, at the same time put your left into very cold water, and after a few minutes take out both hands, and instantly immerse them into water moderately warm, and the right will feel cold, whilst the left feels warm.

## ESSAY VIII.

### OF LIGHT IN PARTICULAR.

THE consideration of the laws of light, as to its refrangibility, its reflection, &c. belongs to the natural philosopher. We have only to consider it as a chymical agent, *i. e.* to notice its influence on other bodies, so far as its presence or absence regulates their chymical changes. We have already considered it as bearing certain relations to heat; we have also noticed its extrication, either from the air, or from the inflammable body during combustion; and we shall in a future Essay find a more appropriate place, for explaining the phænomena of its emission from phosphorus, and certain bodies called phosphorescent. We shall therefore find but few circumstances to attract our attention in this place; but it is of consequence both to the chymist, and the manufacturer, to be aware, that the presence or absence of light is of more moment in a variety of operations, than it is generally conceived to be.

Nitric acid, when exposed to the sun's light, undergoes a gradual change, that would not take place if the light were wholly excluded from it. It first becomes of a straw colour, and then passes to a deep orange, and its other properties are at the same time



altered. The light is supposed to unite with the oxygen of the acid; for the coloured liquor certainly contains a less proportion of that acidifying principle, and oxygen gas is extricated from it during the action of the sun's light.

This points out the necessity of keeping nitric acid, or aqua fortis, in painted bottles, or otherwise secluded from the light. Kept in this manner it undergoes no changes, but without this precaution it acquires other properties, by which both the chymist and the manufacturer, particularly the dyer, may in some cases be disappointed.

Very many coloured bodies are faded, or otherwise changed in colour, by long continued exposure to the light. This can only be in consequence of its effecting some chymical change in the colouring matter, whether it be an artificial dye or the natural colour of the substance. The druggist, aware of this, should keep his digitalis, or fox-glove, and other green vegetable powders, in bottles painted black, as the best means of preserving their colour, and probably their medicinal virtues; for there is great reason to believe, that the same chymical change that affects their colour diminishes their virtues as medicines.

That the fading of colours by exposure to the sun's light is a chymical effect, produced by the light upon the colouring matter, appears evident from its affecting differently articles dyed with

different substances, though of the same colour; thus yarn, or other woollen goods, dyed red with kermes, retains its colour longer, and is less faded, than the same dyed red with cochineal. It is also well known that one painter's colours stand much better than another's, in consequence of their being differently prepared.

The operation of light in effecting the fading of colours has been but little attended to; and the particular chymical changes which occur, are but imperfectly understood. In many instances it probably depends upon the attraction or affinity that exists between light and oxygen.

The blue colour of indigo depends upon the presence of oxygen, for the colourless liquor obtained from the plants becomes blue on exposure to oxygen gas, and the gas is at the same time absorbed. This being the case, stuffs dyed blue with indigo will be faded, or lose their colour, by the abstraction of oxygen; and, as light has so strong an affinity for that substance as to decompose nitric acid, it is probable that it also abstracts it from indigo, and thus diminishes and ultimately destroys its colour.

Stuffs dyed green acquire a yellowish tinge by exposure to the light; the destruction of the blue colour by the above means will account for this, for green is a compound of blue and yellow. Purple stuffs in the same way become reddish, that colour being compounded of blue and red.

In attending to the phænomena of vegetation it is found, that the presence of light is absolutely necessary to the health of plants. If it is wholly excluded from them they soon become pale and sickly; they lose the whole of their green colour, grow weak, wither, and die. Vegetables are blanched by the partial exclusion of light; celery, by earthing it up round the roots, and cabbages or lettuces by tying their leaves together. The parts thus kept from the influence of the light, become pale and almost colourless, and are then said to be blanched.

Plants that grow naturally in dark situations are usually of a pale colour; as the *orobanche ramosa*, which always grows under the shade of hemp, the *lathræa* and others, that are found in the shady parts of woods, and a variety of lichens growing upon trees.

If light is admitted only into one part of the room, in which plants grow, they always incline towards that part; nature's laws being in this instance, as in others, so wisely established, and so connected with each other, that where benefit is to be derived from it, the effects of one lead to the completion of another.

This inclination of the plant towards the light bears so much the appearance of voluntary motion, regulated by a knowledge of the beneficial influence of light, that some philosophers have brought it as

a proof that vegetables are endowed with reasoning faculties. But how slight, how futile are their arguments, how false and unphilosophical their deductions; to assume a new power, a reasoning faculty in plants, merely because the confined and imperfect knowledge of man is unable to explain an ascertained fact! How many thousands of phænomena are our weak intellects unable to comprehend! and how many of nature's laws remain yet to be explored! Would it not then be less presumptuous to acknowledge our ignorance; or more reasonable, to investigate the nature of the fact, than rashly to attribute to the vegetable world a faculty that we have no grounds for supposing it to possess?

The presence of light we find to be necessary to healthy vegetation. Its chymical effects are such as to preserve and keep up those changes in the various parts of the plant that constitute health. But this is not all; the Creator of the world, the establisher of all nature's laws, anticipating as it were the accidental wants of individual plants, has so ordained it, that the effects of light shall also be such as to incline the plant, that is but partially exposed to it, towards the light, in consequence of which it receives more and more of its genial influence. This is a beautiful instance of the omniscience and the beneficence of the Creator; and the philosopher viewing it in this light must notice it with admira-



tion, and acknowledge that infinite wisdom is apparent in the minutest of his works.

We confess ourselves ignorant of the means by which light has this particular effect, as we avow ourselves ignorant of the means by which it influences the colours of vegetables; or by which any other at present inexplicable fact is accomplished; but such may become explicable to future chymists, and we ought to engage in the investigation, rather than retard it by the assumption of a new principle. This hypothetical mode of reasoning puts a stop to inquiry by persuading us, that we have explained facts, when we have only expressed them in other, and those more obscure terms.

Besides the effect that light has upon the colour of vegetables, it is only during the influence of the sun's rays that they emit oxygen gas, or pure air. In the day time most plants give out this gas in abundance, by which means the purity of the air is preserved, and a fresh supply of its pure salubrious part afforded, in lieu of that which is destroyed, or, to speak more properly, abstracted hourly from the atmosphere by combustion, respiration, and a variety of other processes.

The presence of light has considerable effects both in the process of bleaching, and in that of tanning. Cloth, exposed in the bleach-field, is whitened more rapidly in the day time than during the night,

and more so in a sunny day than in cloudy weather. In tanning, the process of handling the hides has more effect, if performed in an exposed situation, and whilst the sun shines, than otherwise.

Phosphorus, and such other substances, as emit light by a similar process, which is not dependent on a previous exposure to the sun's rays, will be spoken of in another part of these Essays. But there are certain substances, that seem, when exposed to light, to absorb it, and afterwards gradually to part with it again, so that when taken into the dark, they become luminous. Most bodies possess this property more or less, but some more remarkably so, than others.

A mixture of sulphur and lime forms Canton's phosphorus, and that of sulphur and an earth called barytes, the Bolognian phosphorus; but these substances differ widely from phosphorus, strictly so called.

To make the former, mix equal parts of pulverised oyster shells and sulphur, and keep the mixture in a covered crucible, for an hour or two in a strong heat. If this powder is exposed to the light, and then taken into a darkened room, it appears luminous, and continues so for a considerable time. When it ceases to emit light, this property is regained by its being again exposed to the light.

Of other substances, that possess this kind of phosphorescency, a better instance cannot be brought,



than that of white paper. If you shut yourself up in a darkened room, and contrive the means of exposing a sheet of writing paper to the sun's rays on the outside, and then drawing it into the room, you will perceive the paper, when first drawn in, to be very luminous. It gradually becomes less and less bright, until it emits no light at all; but you may again restore its brightness by again exposing it to the light.

Even the hand, when first withdrawn from sunshine into a darkened room, emits light in the same manner.

The light thus emitted is in many instances increased by heat; thus if a warm heater, such as is used in ironing, is drawn backwards and forwards over the sheet of writing paper, after it is drawn into the darkened room, the paper is rendered more luminous, and is made to give out light for a longer time. Moreover, when it no longer emits light, its brightness may in some measure be renewed by the heater, without again exposing it to the light.

Sulphate of barytes or heavy spar, and the fluuate of lime or fluor spar, only emit light when heated.

Other substances are made to emit light by attrition, as when you break a lump of sugar in the dark, or scrape with a knife pieces of phosphorated limestone. It is interesting and useful to be made acquainted with these facts, although we must at

present acknowledge our ignorance respecting the cause of them.

Every one knows that light is emitted during the passage of the electric fluid from one body to another. This in its passage from one cloud to another, from a cloud to the earth, or from the earth to a cloud, constitutes lightning. With an electrical machine many very amusing experiments may be performed, by exhibiting the light in a variety of ways; but the consideration of this belongs to the natural philosopher, not to the chymist.

When the back of a cat is stroked by the hand in the dark, small flashes of light or sparks are emitted, and at the same time a crackling noise is heard. This is an electrical phænomenon.

In the night time flashes of light are sometimes observed to be given out by certain flowers, particularly those of the marigold. Many attribute this also to the electric fluid, but in some cases it probably occurs from the disengagement of a phosphoric gas.

## ESSAY IX.

### THE GASSES.

#### OXYGEN GAS, OR PURE AIR.

THE simple substances or elements, that come next in order to be considered after heat and light, are oxygen, azote, and hydrogen. They are never found alone or uncombined either in a solid or fluid state; but chymically united to so much heat as to give them a gaseous form, they constitute the simple gasses. In this state we shall treat of them, but shall first premise a few observations on gasses in general.

What chymists have now agreed to call gasses, differ from vapour, in being permanently aëri-form in every degree of temperature. No degree of cold is able to condense them into fluids or solids.

Water is raised in the form of vapour by heat, and is again reduced to the state of water by the abstraction of its heat. Sulphur or brimstone is converted into vapour, when heated, and this vapour is condensed into a solid form by cold, or by abstraction of heat. But the common air of the atmosphere, in which we live and breathe, is not reducible to a fluid

or solid state by any degree of cold, be it ever so intense; it is therefore a gas.

All gasses are invisible, but still we cannot doubt of their existence, for we can retain them in proper vessels, pour them from one to another, separate, or combine them at pleasure, and ascertain the particular properties of each.

Every thing, which in common language we call empty, is full of air or gas, and the method we employ, for pouring it from one vessel into another, is this: invert the jar, for instance, which contains the gas, in a tub of water with its mouth under the surface of the water; fill the jar which is to receive the gas with water, and invert it in the same tub; then incline the first jar, so that its mouth shall be under that of the second, and the gas will immediately ascend in bubbles to the top, and the water will rush in the same proportion into the first jar, till all the gas has left it, and passed into the other.

Though all gasses are invisible, they are easily proved to be different; and each to possess its distinct properties. A lighted candle immersed into a jar of one kind of gas will burn in the usual way, in another it burns with a much more brilliant flame, and in a third it is immediately extinguished.

These different properties will be discussed, in treating of the different gasses separately; but at present only the simple gasses, namely, the oxy-

genous, the azotic, and hydrogenous, will be treated of; the compound ones, as carbonic acid gas, and others, will be considered under the head of the simple substances, to which they owe their chief properties.

*Oxygen Gas.* Take a small apothecary's phial, into which put an ounce or two of manganese, and pour thereon a sufficient quantity of sulphuric acid, to form a liquid paste. Afterwards fit a cork to the mouth of the phial, with a hole through it, into which insert a recurved tube, with one of its extremities entering the bottle, while the other is placed under the mouth of a jar, or phial, filled with water, and inverted in a tub of the same. The tub should be furnished with a shelf, with holes in it, upon which the phial may rest in its inverted position.

When the apparatus is thus disposed, apply the heat of a lamp to the phial containing the manganese, and a gas will immediately be disengaged, which is called oxygen gas, or vital air.

It derives the first name from its property of converting a variety of substances into acids, when combined with them, and from its being indeed the acidifying principle of all acids. It is called vital air, because its presence is absolutely necessary to support the life of animals. Beside these two properties, it has that of supporting and being necessary to combustion.



- These three are the distinguishing properties of oxygen gas, and are possessed by no other simple gas. Common air has the same, only in consequence of its containing oxygen; and in proportion as it contains more, it supports animal life and combustion in a greater degree.

The acids and their compounds will fall naturally to be considered, when treating of the base of each acid. There is one however of the mineral acids, which has not hitherto been satisfactorily decomposed, and of which the base consequently is not known. This is the *muriatic or marine acid*, or, as it was formerly called, spirit of salt. As there is every reason to believe, that it is a compound, and that oxygen is in this, as well as in all the other acids, the acidifying principle, we cannot treat of it with more propriety in any part of the work, than in this.

The muriatic acid is procured from common salt, by distilling it with sulphuric or vitriolic acid. It comes over in the form of fumes, which are collected and condensed. This acid, further oxygenated; is employed, either alone under the name of oxygenated muriatic acid, or combined with potash, when it is called oxymuriate of potash, in the improved method of bleaching, which has been of late so advantageously adopted.

The oxygenated acid is procured, when three parts of the acid, and one of a mineral called



manganese, are heated together; and if the vapours are received into a solution of potash, the oxymuriate is produced. The same acid is likewise obtained by pouring twelve parts of vitriolic acid, previously mixed with an equal quantity of water, upon a mixture of sixteen parts of common salt with six of manganese. The vapours in this process may likewise be received into a solution of potash.

The acid is thought fittest for the bleaching of muslins, and the neutral salt is more generally employed for other goods. For whitening raw silk, a mixture of twelve ounces of the acid with forty-eight pounds of spirits of wine is preferred.

In bleaching with this acid, it is used considerably diluted, and the goods are previously boiled in a solution of potash. Being then steeped in the acid, they are afterwards washed in clear water; and the same process is repeated as often as it is found necessary.

*Common salt*, from which muriatic acid is procured, is a compound of this acid with the fossil alkali. It is found in three situations; in large beds in the bowels of the earth, when it is called rock salt; in springs of water which derive their source in or near these beds, when it is called spring salt; or in the water of the sea, when it is called sea salt.

The rock salt is seldom used, till it has been dissolved in water, and separated again by evaporation.

Brine may be evaporated, either by exposure to the sun's rays, or by artificial heat. In warm countries, the former method is adopted; where, by receiving the sea water into proper reservoirs, that are made extensive and shallow, the salt is left covering the bottom of the pits, after the water has been evaporated by the heat. Salt, thus procured, is called bay salt. In our climate the heat is insufficient, and the rains too frequent, to allow of this plan being adopted with advantage; our salt is therefore procured by boiling the brine, and is of different degrees of purity, according to the heat, and as it is deposited in the latter or early part of the process.

The uses of common salt as a condiment, and as a preservative of meat, are sufficiently well known; but it is not so generally understood, that in small quantities, instead of retarding, it promotes putrefaction, which is the case.

Salt is a useful condiment to cattle as well as man. In some parts of Africa large herds of animals travel at stated seasons to the coast, where the salt plants abound. The fattening quality of our own salt marshes is well known to graziers. And in many countries it is the custom to give salt with the food to most kinds of cattle.

When a candle or a piece of burning charcoal is introduced into oxygen gas, it burns much more rapidly than in common air, and the charcoal emits beautifully bright sparks.

If an iron wire twisted spirally, and having a small piece of burning phosphorus, or sulphur, at the extremity, be introduced into a jar of this gas, the iron itself will be burnt, emitting sparks, and bright corruscations, during its combustion.

By directing a stream of this gas through a blow-pipe to the flame of a candle, or any other combustible body, that is ignited, the most intense heat may be produced, that art has been able to effect. Metals and earths may thus be fused that resist all other means.

During combustion in oxygenous gas the volume of the gas is decreased, and, if the combustion be continued long enough, the gas wholly disappears. A union has taken place between the oxygen and the combustible body, and the result in many cases is an acid. Thus, if sulphur is burnt, sulphuric or vitriolic acid results; if phosphorus, phosphoric acid; and if carbon, or charcoal, carbonic acid.

When combustion takes place in COMMON AIR, the same phenomena occur, but less rapidly, and to a less extent. If phosphorus be burnt in a jar of common air, inverted over water, part of the air is absorbed, which is shown by the water rising in the jar; and the phosphorus is, part of it, con-

verted into phosphoric acid, which proves that it is oxygen that is absorbed. The air that now remains, which is  $\frac{73}{100}$ ths of the whole, is no longer capable of maintaining combustion, or life; a candle put into it would be extinguished, and a mouse or any small animal would soon perish. From this circumstance it is called azotic gas, or impure air, which is thus proved to be the other constituent part of common air.

Common air then is a compound of oxygen gas and azotic gas in the proportion generally of 27 parts of the former to 73 of the latter. The grand uses of the air are well known to be, to maintain life and combustion; and as its pure part is thereby abstracted, a continual supply becomes necessary, where those processes are carried on.

That a continual supply of air is necessary to support life by respiration, is made evident by animals dying in an exhausted receiver, and living only for a given time in a given quantity of air; a longer time the larger the quantity. A mouse, for instance, confined in a jar of common air, the mouth of the jar being closed, would presently become uneasy, would gasp for breath, become convulsed, and, if allowed to remain in this situation, would soon die; but if fresh air be in time admitted to the jar, the mouse would revive.

This shows us, how important it is to renew the fresh air of the rooms we live in, and to admit a



supply as fast as the pure part of it is abstracted by breathing, and by the burning of fires and candles. Instead of doing this, it appears, as if we conspired all we could to stop every avenue to its ingress. We shut the windows as close as possible, and put list round the doors; but luckily for us, all we can do to stop its entrance, is ineffectual. Such is the disposition of the air to restore its equilibrium, that where there is a fire, to heat the air, and convey it up the chimney, the external air presses with such force, as to make its way through every crevice.

We do, however, in many cases succeed so far in preventing the access of fresh salubrious air, as to prove its baneful effects. In our theatres and ball-rooms the vitiated air has so little opportunity to escape, and the fresh air so little to enter, that in some parts a candle will scarcely burn; and an oppressive weight across the chest speaks plainly to our feelings, that we want a freer atmosphere.

In the narrow streets and lanes of manufacturing and commercial towns, pestilential diseases are almost always prevalent, and the inhabitants of these places carry in their squalid countenances the marks of constitutional illness. All this in a great measure proceeds from the want of pure salubrious air.

Our prisons and our poor-houses are too frequently, from the same cause, the residence of disease. Although much, I am happy to say it, has of late years been effected towards remedying



these grievances, much still remains to be done; and the improvements for ventilating apartments, and maintaining the purity of the air, will not, I hope, be confined to these or similar buildings.

Not only our hospitals, our prisons, and other public buildings, require ventilation, and airy situations; but our private houses, and particularly those of the poor, demand the same. The site and plan of a town is of national importance, for the health of its inhabitants must be greatly influenced thereby.

The proper ventilation of our apartments ought to be strongly inculcated by those, who are aware of its utility, that it may become more generally adopted; and the ignorant should be informed of the best modes of accomplishing it.

Every window or casement should be made to open, and that always at the top. These should be opened when we leave the room; and in warm and moderate weather may be frequently opened for a short time whilst we are there, particularly if many persons live in the same apartment. Much good would accrue from attention to this circumstance in manufactories, where many persons are breathing the same air for several hours together.

In every situation it is proper to let down the sash, or open the window, of sleeping apartments before we leave them.

In many rooms it will be requisite to have a con-

slant communication with the external air, by means of an opening in some part of it near the floor. In this case, and indeed in every case of ventilation, the vitiated air will have exit at the top, and the fresh air will come in at the bottom; for the air that we have breathed and vitiated being heated, immediately ascends and occupies the top of the room; whilst the fresh air, being colder, and of course heavier, comes in at, and occupies the lower part of the room. That this is the case will appear evident by the common experiment of holding a lighted candle in different parts of the door-way of a room heated by company. The flame is driven outwards when held near the top, but into the room, when the candle is held near the floor.

When a window opens from above downwards there can be no inconvenience felt from sitting near it; for no cold air, as is usually imagined, enters by the window, as will appear by holding a candle near the opening.

The way to prevent a current of cold air from the opening at the bottom of the room is, to have a slanting board, to direct it some way upwards. In rooms having a plaster partition, or any other double partition, perhaps the best plan would be to make an external opening through the outer plaster near the ground, and an inner one near the ceiling, or at least above the heads of persons in

the room, that they might suffer no inconvenience from the cold air.

That combustion, as well as respiration, vitiates the air, and requires a continual supply, is evident from a candle only burning a certain time, if confined in a close jar, and by the same continuing to burn a longer time if fresh air be admitted to the jar.

This makes the ventilation of rooms still more necessary, where there are candles and fires burning; and it is, in my opinion, a great objection to our mode of warming apartments by open fires. If warmed by stoves, the ash-pits of which are without, the air in the rooms would not be vitiated by the combustion; less cold air would be required, and, consequently, our rooms would be both warmer and more wholesome.

Besides this, all parts of the apartment would be nearly equally warm, and we should not experience the cold draughts of air that often starve us behind; whilst we are in other parts almost burnt by sitting near the fire; which irregular warmth proves the cause of rheumatism, chilblains, and a variety of ailments.

Besides the uses of common air, which we have enumerated, it answers a variety of other important purposes. The oxygen is absorbed from it in the calcination of metals. It is necessary in most cases of fermentation. By the expansion of air when

heated, it becomes an easy means of transmitting or communicating heat, and thus preserves its equilibrium, or an equal temperature; and, lastly, by its power of dissolving water, and holding in solution more or less according to its temperature, it becomes the immediate cause of spontaneous evaporation, and of dews, fogs, rains, and similar phenomena.

There is constantly going on an evaporation of water, to a very great extent, from the seas, lakes, rivers, and from the whole surface of the earth, wherever there is moisture. The sea, it has been found by calculation, loses many millions of tons daily by this process; which loss is supplied by the rivers, that are constantly flowing into it.

The evaporation is increased both by heat, and by the agitation of the air; and therefore a warm and windy day is the best for drying any thing exposed to the air. The wind assists by removing the air, that becomes saturated with water, and thus admitting access to such as is not. It answers the same purpose as stirring does in promoting the solution of salt in water. The heat aids the evaporation by increasing the solvent powers of the air, in the same way that it promotes the solution of salt in water, and enables it to dissolve a greater quantity.

On this property, that air when heated is able to hold or retain more water than when cold, depends the explanation of a variety of phenomena. Hot



water will dissolve more salt than cold water; therefore hot water, that is saturated, will deposit part of the salt on cooling. In the same way, and for the same reason, hot air, that is saturated with moisture, will deposit part of it in form of dew, rain, &c., when it becomes cold.

During the day-time the sun's rays having warmed the earth, and that portion of air that is near its surface, this stratum of air is enabled to hold a good deal of water in solution. But when the sun sets, the earth and adjoining stratum of air are so much cooled, that the latter is unable to hold all the water, which it had formerly dissolved, and the consequence is a deposition of it in the form of *dew*.

Dews are seldom seen more than a very few feet above the ground, because the stratum of air cooled by the absence of the sun extends no higher. Pictet has ascertained by experiment, that the air is colder near the surface than some feet above it during the night, and warmer during the day.

In the morning, when the sun has warmed the earth, and lower stratum of air, sufficiently to enable this to dissolve all the moisture, that it now contains, there is no longer any deposition, and consequently no more dew.

Dews are most frequent, and most abundant, when there is the greatest difference between the temperature of the air in the night, and that in the



day, as in the autumn, when very cold evenings succeed to very warm days.

A haze, mist, or fog, is a similar deposition from a larger body of air, extending to a greater height. The cause of this deposition is supposed to be the passage of a colder or a warmer stream over one that is of a different temperature, or the meeting of two streams not equally heated; in which case the mixture is unable to hold all the water in solution, that they held when separate.

In clouds the water is probably in the same state as in mists, but the warmth of the inferior strata prevent its falling below a certain point.

When two clouds meet that are of different temperatures, or in different states of electricity, I conceive that a further deposition ensues; and that according to the temperature, and the suddenness of the deposition, the water assumes the form of rain, snow, or hail.

Saussure supposes that water exists in three different states in the atmosphere; first, in a state of vapour, that is invisible, as when evaporated from moist bodies; secondly, in a vesicular form, as in clouds, where it exists in small bladders or vesicles; and, thirdly, in a true aqueous form, as in rain. He supposes that in these three states its capacity for heat is different; that the vapour has a greater capacity than the vesicular state, and the vesicular greater than the aqueous state.

According to this supposition there will be an evolution of heat when vapour is converted into dews, fogs, and clouds; and again when the latter are converted into rain, snow, or hail. Accordingly, it is frequently observed, that a shower in cold weather, or a fall of snow, warms the air. And it may be added, that Pictet observed his thermometer, at the top of a pole 75 feet high, to rise between one and two degrees, when surrounded with a fog.

By the various means, which we have now mentioned, all the water that is evaporated, and taken up by the air, is again deposited in rain, and dews, to support the life both of the animal and vegetable world. It is then carried by the streams and rivers to the ocean, to be again evaporated, and answer again these beneficial purposes.

When a glass of cold water is brought into a warm room, or a bottle of wine out of a cold cellar, a dew is immediately deposited on the outside; this is because the warm air in contact with the glass is suddenly cooled, and thereby rendered incapable of retaining all the moisture which it had previously dissolved.

In a warm room, where there are many people, and consequently much moisture for the air to absorb, a dew is deposited on the inside of the windows; because the cold external air cools, through the medium of the glass, that portion of the internal

air that is nearest to it, which of course deposits its moisture.

When the air in the room is colder than the external air, a dew is deposited on the outside of the window.

In winter time the dew deposited on the inside of the windows is frozen, assuming very grotesque appearances, as observed in a frosty morning.

## ESSAY X.

### AZOTIC GAS, OR IMPURE AIR.

AZOTIC gas exists in great proportion in the atmosphere; being, as we have already said, one of its constituent parts. Whenever we abstract the oxygenous gas from common air, the residue is azotic gas. If therefore we burn a candle or any other combustible body in a jar containing common air, the remaining air after combustion is azotic gas or impure air; and if the combustible body is phosphorus, the gas is tolerably free from any admixture.

A candle immersed in this gas instantly goes out; and if an animal is confined in it, it soon dies. Its presence in the atmosphere seems to temper and moderate the action of the oxygen; for without it combustion would be too violent and rapid, and the oxygen breathed alone would excite inflammatory complaints and soon prove fatal.

Azotic gas is emitted during animal putrefaction. It is given out by ripe fruit, and by flowers; hence the impropriety of keeping either in apartments where we live. The air is considerably vitiated by keeping pots of flowers in close rooms, as in bed-chambers; and bad effects have frequently proceeded from it. Mushrooms are observed to evolve

this gas, whilst growing, and to afford more when chymically analyzed than other vegetables; they approach in this respect to the composition of animal matter.

It is a subject, that requires further chymical investigation, to ascertain the particular changes, that are effected during the putrefaction of animal matter. We might be enabled by it to discover better means, than are now known, to preserve meat; and probably to recover it after the putrefaction has commenced. We know that the presence of air is necessary to putrefaction, and that warmth and moisture promote it; we therefore prefer a cool and dry situation for our larders. Meat may be long preserved in vessels of fixed air, and means might, I think, be invented for making this an easy practice. Meat that is considerably tainted, may be rendered more palatable, either by burying it for a few hours under ground, or by covering it with powdered charcoal. The meat of animals, that have been hunted, or otherwise violently exercised, inclines very quickly to putrefaction, and is consequently tenderer than other meat kept the same length of time. Animals killed by lightning, or by a strong electric shock, which is the same thing, have the same disposition to putrefy; and the latter mode has been recommended for killing poultry, that is to be eaten immediately.



The combination of azote and oxygen, besides affording common air, which we have already treated of, constitutes a variety of other substances, according to the proportions of the two ingredients. Nitric acid or aqua fortis is a compound of these two elements, and may be made by repeatedly passing electric shocks through a mixture of oxygenous and azotic gas. The analysis of this acid proves the same thing; for when it is made to pass through a red-hot porcelain tube, a mixture of oxygenous and azotic gas is obtained.

The process used in manufacturing the aqua fortis for commerce, consists in mixing one part of saltpetre with two or three of red bolar earth. This mixture is put into coated retorts, disposed in a gallery or long furnace, to each of which is adapted a receiver. The first vapour, that arises in distillation, is nothing but water, which is suffered to escape at the place of juncture, before the luting is applied; that is, before the juncture is closed up with a composition of meal and water, or with glazier's putty, or some other substance, called luting. When the red vapours begin to appear, the phlegm, which is condensed in the receiver, is poured out, and the receiver being replaced is carefully luted to the neck of the retort. The vapours, which are condensed, form at first a greenish liquor; this colour disappears insensibly, and it then becomes more or

less yellow. This is the common aqua fortis, which requires purification for chemical purposes.

It may also be obtained by distilling the sulphuric acid upon nitre or saltpetre. When pure, it is colourless. It is used in dyeing, and in several processes by the manufacturers in metals, as in gilding, &c. In consequence of its dissolving metals it is used in etching upon copper. It is also a useful medicine in a variety of complaints.

Nitric acid has a peculiar effect upon animal matter, converting it into a fatty substance, very like spermaceti. The same conversion of animal matter into an inflammable substance has been observed to be effected by a natural process in certain situations.

Touret, a French physician, has described the appearances met with on opening a vault in the burial ground des Innocents. Many of the bodies, that had been buried a great number of years, were found to retain their form, and consistence, and in many respects their natural appearance. When they were examined, it was ascertained, that most parts of the body were converted into a fatty or rather spermaceti-like substance that was inflammable, and burned like spermaceti.

Dead animals thrown into running streams have undergone a similar change in many of their parts, particularly the flesh or muscular parts. And nitric acid poured upon a piece of flesh has been disco-

vered to effect the same change. From these facts there is little doubt, but that by proper management horseflesh, and that of animals dying of disease, might be converted to the useful purpose of making soap or candles.

SALTPETRE, from which aqua fortis is obtained, is a combination of this acid and potash. It is procured sometimes by natural processes, sometimes by artificial means.

In some countries the soil contains it, where they have only to collect what effloresces on the surface; wash it well, boil the water, evaporate, and then crystallize the salt. It is found in this state in the Indies, and also in some parts of Spain.

In general, however, it is formed artificially by collecting animal and vegetable substances into heaps, and suffering them to putrefy. The animal matter affords azote, which attracts oxygen during putrefaction, and thus forms nitric acid. The vegetable matter affords potash, which uniting with the new formed acid constitutes the nitre.

In the North of Europe these saltpetre beds are formed with lime, ashes, earth of uncultivated grounds, and straw, watered with urine, dung-hill water, and mother waters \*.

Of animal matter, blood, and next urine, favour the production of saltpetre most. Of vegetable matter, light minutely-divided earth, in which plants

\* Refuse waters from various manufactures.

have grown and decayed successively for ages, is fittest to form these beds.

From the artificial as well as natural nitre-beds the salt is extracted by washing the earth in water, evaporating, and then crystallizing.

Obtained by this first operation the salt is never pure, but contains common salt, and an extractive colouring principle, from which it must be cleared. For this purpose it is dissolved in fresh water, which is evaporated, and to which bullock's blood may be added, to clarify the solution. The nitre obtained by this second process is termed *nitre of the second boiling*.

The purified nitre is employed in making the better sort of aqua fortis, and in the composition of gunpowder. Saltpetre of the first boiling is made use of in manufacturing an inferior aqua fortis for the use of dyers.

We have said that saltpetre is an ingredient in *gunpowder*. This powerful composition is a mixture of seventy-five parts of saltpetre, nine and a half of sulphur, and fifteen and a half of charcoal. This mixture is triturated from ten to fifteen hours in pounding-mills, having their pestles and mortars of wood, care being taken to moisten it from time to time. It is then passed through sieves of skin, and granulated. The powder is then sifted to separate the dust, and, lastly, carried to the drying house.

Cannon powder requires nothing further; but for fowling powder, the process of glazing is necessary. This is done by putting it into a kind of cask, which turns upon an axis, by the motion of which the angles of their grains are broken, and the surfaces polished.

In the composition of gunpowder, it is not necessary to attend exactly to the proportions directed above; for, although the proportion of saltpetre cannot be varied much without detriment, that of the other two ingredients may vary considerably, without very materially altering the properties of the powder. The purity of the materials is of very considerable consequence, and so is the circumstance of their being very intimately mixed. If the saltpetre contains any portion of common salt, which is usually the case with the inferior sorts, it injures the powder by attracting moisture from the atmosphere. Gunpowder moistened by this cause, or by any accident, loses its power, in consequence of the water dissolving the saltpetre, and separating it from the other ingredients. When thus damaged, if by pure water, it only requires to be again powdered and regranulated; but if salt water has caused the damage, it cannot be remedied; the ingredients, however, are valuable, for the saltpetre may easily be separated by solution and crystallization.

The effects of gunpowder are owing to the sudden formation of a quantity of gas, and are consequently



greater when the gas is confined in all directions but one, as in our guns and cannons. The nitric acid of saltpetre is decomposed, and affords the gas. The other ingredients dispose it to be easily inflamed, which is necessary to the decomposition of the acid.

A *fulminating powder*, possessing far greater powers than gunpowder, is formed by mixing and triturating three parts of nitre, two of salt of tartar, and one of sulphur. A few grains of this heated in an iron ladle over the fire is first melted, then affords a blue flame, and at last a violent explosion.

When the nitric acid is poured upon iron, copper, or zinc filings, there is a considerable disengagement of air, which assumes a red colour, but which, if collected in a jar previously filled with water, and inverted in a tub of the same, is colourless, and is known by the name of *nitrous gas*.

Nitrous gas is, like nitric acid, a compound of oxygen and azote; but in this the proportion of oxygen is much smaller. It will support neither combustion nor animal life.

When mixed with oxygen gas it unites and forms nitrous acid, which appears in red vapours. When mixed with common air the same takes place, which is the cause of the red vapours that appear when the nitric acid is poured upon the iron or copper filings.

As the nitrous gas combines only with the oxygenous or pure part of common air, it has been employed to ascertain the quantity of oxygenous

gas, and consequently the purity of the air. Used in this way, it is called a *eudiometer*. For this purpose, a given quantity of nitrous gas is added to a certain quantity of common air, or any other, that is required to be examined. The mixture is made in a graduated tube over water, and in proportion to the quantity of oxygen the volume of air is diminished, and the water rises in the tube. The height to which the water rises is the measure of the purity of the air.

By exposing nitrous gas for a few days to iron filings, it loses part of its oxygen, and then constitutes a gas called *nitrous oxyd*, which is consequently a compound of oxygenous and azotic gas with a less proportion of the former even than nitrous gas.

Nitrous oxyd may be obtained by a variety of other means, but the purest is got by the following process, as directed by Mr. Henry. To diluted nitric acid add carbonate of ammonia (the common smelling salts) till the acid is saturated. Then evaporate the solution; and to supply the waste of alkali, add occasionally a little more of the carbonate. Let the solution be evaporated by a very gentle heat to dryness. The salt thus obtained is next to be put into a glass retort, and distilled with a sand heat, not exceeding 500° Fahrenheit. The heat of an Argand's lamp even is sufficient. The gas may be collected over water, and allowed to stand a few

hours before it is used; during which time it will deposit a white cloud, and will become perfectly transparent.

The great peculiarity of this gas is, that it supports combustion, and not the life of animals. Most inflammable bodies, as charcoal, sulphur, phosphorus, and even iron wire, burn in this gas with nearly as much rapidity and splendour as in oxygen gas. The nitrous oxyd is decomposed, and its oxygen unites to the inflammable body.

When an animal is wholly confined in this gas it speedily dies, but when breathed for a short time from a bladder or oiled-silk bag it has a very extraordinary effect. We have very respectable testimonies to the peculiar sensations it excites, in an essay published on the subject by Mr. Davy.

Most persons express their feelings on the occasion, as highly pleasurable. They experience great exhilaration, and feel an irresistible propensity to laughter, as well as an unusual disposition to muscular exertion. Their ideas are vivid, and flow rapidly; and, in short, they experience what most persons do in the pleasant period of intoxication, without suffering any of the unpleasant effects that usually succeed intoxication.

With the various compounds of oxygen and azote now described, we finish the consideration of those elements, and pass to that of hydrogen.

## ESSAY XI.

### HYDROGEN GAS, OR INFLAMMABLE AIR.

HYDROGEN, as its name imports, is a constituent part of water, of which oxygen is the other ingredient. It is from the decomposition of water that we obtain hydrogen gas, and this is done in a variety of ways. We shall describe only two; the first of which is the most easily accomplished, and the latter is most economical, which is of consequence, when a large supply of this gas is required.

The first mode only requires you to pour sulphuric acid, or oil of vitriol, previously diluted with five or six times its weight of water, upon iron filings, or small iron nails, in a phial or glass retort with a recurved tube. An effervescence will ensue, and the escaping gas may be collected in a jar under water.

To obtain this gas in the large way, procure a gun-barrel, the breech of which has been removed, so as to form a tube open at each end. Fill this with iron wire, coiled up in a spiral form. To one end of the barrel adapt a small glass retort, partly filled with water, and to the other a bent glass tube, the open end of which terminates in

the receiving vessel. Let the barrel be placed horizontally (or rather with that end to which the retort is fixed a little elevated) in a furnace having two openings in its body opposite to each other. Light a fire in the furnace; and, when the gun-barrel has become red hot, apply a lamp under the retort. The steam of the water will pass over the red hot iron, and will be decomposed. Its oxygen will unite with the iron, and its hydrogen will be obtained in the form of a gas.

This gas burns with a silent lambent flame, when in contact with common air; hence its name of inflammable air. When previously mixed with common air, an explosion takes place on the approach of a lighted match or candle. This gas of itself, however, extinguishes a burning body; thus, if a jar containing inflammable air is brought in an inverted state over the flame of a candle, and depressed, it immediately extinguishes it. Its other properties are, that animals confined in it soon die, though plants live and thrive in it, and that it is very considerably lighter than common air.

Knowing it to possess these properties, we shall be able to explain many very curious facts.

ARTIFICIAL FIREWORKS are made by passing this gas through metallic tubes, variously disposed, and furnished with a variety of orifices, through



which the gas can escape. The machine, to which these complicated tubes are affixed, is made moveable wholly, or in part, and in different directions, so as to add much to the effect. The gas is inflamed at all these orifices, where it comes in contact with the atmospheric air, and burns with a still flame.

A constant stream of it is supplied by pressing the bladders, or bags, that contain it, and that are connected to the main tubes, from which all the others branch out.

The most common explanation of the AURORA BOREALIS, or northern lights, is, that a stratum of hydrogenous gas above the atmosphere of common air is lighted by the electric spark, and burns slowly, where it comes in contact with our common air. The 'corruscations of light observed chiefly in northern latitudes are perhaps referable to the same cause. The levity of this gas, compared with that of common air, will account for its occupying a higher region; and, as it can only burn, where it is in contact with the latter, the appearances we observe in the aurora borealis are exactly such as we should expect from such a cause.

Inflammable air or hydrogenous gas is frequently extricated in mines, probably from the decomposition of bituminous or coaly substances. It is called by the miners FIRE-DAMP; and is to them a source of great danger, as well as inconvenience;

for, by becoming mixed with the common air, it is subject to sudden and violent explosions, whenever a lighted candle or other ignited body is accidentally brought into contact with it.

In stagnant muddy water, where the putrefactive process is constantly going on, both of animal and vegetable matter, there is a considerable disengagement of inflammable air, which is seen rising to the top in bubbles. It is easily collected by inverting a wide-mouthed jar, filled with water, in one of these stagnant pools, where the bubbles are observed, and then stirring up the mud from the bottom with a stick. This agitation causes a more rapid disengagement of the gas.

The gas thus procured is found to contain a considerable portion of another gas, viz. the carbonic acid gas or fixed air. The evolution of these gasses from such marshy situations is in consequence of the decomposition of water by the putrefying animal and vegetable matter. The oxygen of the water uniting with the carbon of the putrefying mass forms the fixed air, whilst the hydrogen of the water escapes in the form of hydrogen gas.

It must be remembered that the bubbles of air seen to arise from streams, and clearer water, in which the green conferva and other vegetables grow, as the duck-meal (*lérna*), or chick-weed (*alsine* or *stellaria media*), is pure air or oxygenous gas, and not this inflammable air.

In consequence of this gas being so much lighter than common air, it has been applied to the purpose of forming AIR BALLOONS. A bladder or bag, made of waxed canvas, or oil-skin, when filled with this gas, is much lighter than the same bulk of common air, and therefore rises from the ground when liberated, as naturally, and by the same law, as a cork pressed down under water, rises to the top when the force is removed.

The larger the balloon, the greater weight it is able to raise with it; but the higher it mounts, the less weight it is able to carry.

The reason of this latter circumstance is, that the higher it gets the rarer is the air, and consequently the less is the difference between the specific gravity of the air in the balloon and the surrounding air.

On this depends the utility of carrying ballast, when it is required to mount high in the air. The more ballast your balloon is able to raise, by being made large, the higher you may ascend; for by gradually throwing out the ballast, you mount still higher in the air. When it is required to descend, the inflammable air is suffered gradually to escape from the balloon; by which means it becomes specifically heavier than the atmospheric air, and consequently falls gradually to the ground. The inconveniences experienced by aeronauts, when the balloon has reached the ground,

in consequence of its rebounding, and often dragging the travellers to a considerable distance, might be obviated by contriving the means to let the whole of the gas escape as soon as the balloon has touched the ground.

Another kind of balloon is formed by filling the bag with heated air - instead of hydrogenous gas, and by keeping it in the same heated state, which is done by means of a fire under the balloon, having a communication with its cavity. The air in the balloon in this case being rarefied, and made specifically lighter than the surrounding air, rises and carries a weight with it upon the same principle as the first kind of balloon.

An amusing experiment, proving the lightness of this gas, may be performed by forming soap bubbles with it instead of common air. For this purpose fill a bladder with the gas; if the bladder is furnished with a stop-cock it will be more convenient; and then adapt it to a common tobacco pipe. Dip the bowl of the pipe into a lather of soap, and by pressing the bladder blow it up into bubbles. These bubbles, from their extreme levity, rise very rapidly.

We have said that hydrogen and oxygen form WATER; and, in the experiments detailed for procuring hydrogenous gas, we have proved it analytically; for whilst this gas comes over, the other

constituent, oxygen, is united to the metal, that is employed.

We have also synthetical proofs of this composition of water, one or two of which we shall recite; and these we trust will suffice. When a mixture of hydrogenous and oxygenous gasses is made to explode, there is always a formation of water; but in a single experiment it is too minute to be completely satisfactory, although a dew may generally be observed to be deposited on the sides of the vessel in which the experiment is performed.

By the slow but continued inflammation of hydrogen gas in common air, a sufficient quantity of water may be formed to satisfy any one with respect to its composition. This may be done in the following way: fill a bladder, furnished with a stop-cock and pipe, with hydrogen gas. Procure a glass globe, having two openings opposite to each other; then set fire to the stream of hydrogen gas passing from the tube, and introduce it into the centre of the globe. The combustion may be continued, if required, till all the inflammable air is burnt; and drops of water will be observed running down the inside of the globe.

The electrical pistol is a machine contrived for exploding a mixture of inflammable air and common air by means of the electric spark; and the force of explosion is made to drive out a cork, or other solid body, with some violence.



Each time that the pistol is fired, a minute quantity of water is formed; and if the experiment is frequently repeated with the same pistol, its internal surface becomes very sensibly moistened.

In iron foundries, and in manufactories where other metals are melted, very serious accidents have happened from only small quantities of water getting accidentally into contact with the heated metal. If only a few drops of water happen to be in the cast or mould, which is to receive the melted metal, a most violent explosion is sure to ensue, as soon as the metal comes into contact with it. The fluid metal is thrown about in every direction, and the workmen of course are dreadfully burnt. The effect here is much greater than it would be from the mere conversion of the water into vapour; and it is now ascertained, that it arises from the decomposition of the water, and consequent formation of inflammable and pure air; a few drops of water affording a very large volume of the airs.

It is unnecessary to say any thing respecting the important uses to which water is applied. To preserve it sweet during long voyages, it is necessary that the watercasks should be well charred on their insides. This is found to be the best means of preventing the decomposition of the water, which is the cause of its becoming disagreeable to the taste, and unwholesome. Many suppose that water becomes tainted in consequence of the putrefaction of

animalculæ and small vegetables, which it contains; but this is not so much the cause, as a real decomposition of part of the water, which is effected by the juices and other parts of the wood of the cask attracting the oxygen of the water. The hydrogen remains in the water, and gives all the unpleasant properties to it. Charring of the casks is the best preventive. Tainted water may be somewhat recovered by stirring in it powdered charcoal.

## ESSAY XII.

CARBON, OR CHARCOAL :

CARBONIC ACID GAS, OR FIXED AIR.

CARBON is the name given by chymists to the pure part of charcoal. It is present in almost all combustible bodies, and is itself completely combustible. Carbon is not decomposable, and therefore ranks amongst the chymical elements. The most interesting compound, of which it forms the base, is its union with oxygen, when it forms the carbonic acid gas, or fixed air. This compound will furnish us with materials for the present essay ; but first it may be as well to say something of charcoal.

CHARCOAL, as met with in commerce, is obtained from the partial combustion of wood. Billets of any kind of wood are heaped up into piles, usually in the form of pyramids. The whole is then covered with earth, leaving an aperture at top, and bottom for a current of air. The pile is now set fire to, and when completely ignited throughout, the apertures are closed, and the fire consequently smothered. In this process all the juices of the vegetable, its oils, &c., are dissipated, leaving little more than its woody fibre. It loses about three-

fourths of its weight, and what remains is called charcoal.

This charcoal contains, besides carbon, small quantities of different kinds of earth, some water, and, it is now supposed by some, a proportion of oxygen.

When charcoal is burnt, its carbon unites with the oxygen of the air, and so much heat as to give it the gaseous form, and constitutes CARBONIC ACID GAS, or fixed air.

The same gas is also obtained by the combustion of the diamond, proving that this precious and costly article is carbon or charcoal in a very indurated state, and assuming a determinate form. It was not till lately that the diamond was proved to be combustible; but by means of the blow-pipe, and a stream of oxygen gas, it may be, to speak in common language, wholly consumed. The air, that is extricated during the combustion, is carbonic acid gas, proving the diamond to have been chiefly, if not wholly, composed of carbon.

Long before this fact respecting the diamond was ascertained, Sir Isaac Newton, reasoning from its great refracting power, declared it to be his opinion, that it was one of the most combustible of bodies. Modern discoveries have now proved the fact; and it affords us an admirable instance of the acumen of that great philosopher.

The CARBONIC ACID GAS, which we sha now

take into consideration, may be obtained much purer by other means than by the combustion of charcoal. It is this gas that is extricated in almost all cases of effervescence, as when vinegar, or any other acid, is poured upon chalk, marble, limestone, or potash.

The best way of procuring it for experiment is, to pour diluted sulphuric acid upon chalk in a common phial, furnished with a bent tube. The gas may then be received in jars over water.

It possesses the following properties : it is much heavier than common air : it extinguishes flame, and is fatal to animals : it possesses the properties of an acid, and precipitates lime from lime water.

By keeping in mind these properties, we shall be able to detect the presence of this gas under a variety of circumstances, and thus be enabled to account for various interesting phænomena. We shall find that it is extricated during the fermentation of beer, and other liquors ; that it is formed during many instances of combustion, and by the respiration of animals ; and, also, that it is met with naturally in certain mineral waters, and in many other situations.

*Fermentation* is the term used to signify those changes that take place in dead animal and vegetable matter, when exposed to the action of the air, and kept at a certain temperature. If the saccharine or sugary principle predominates in the substances



employed, the product will be a spirituous liquor, and the process is called the spirituous or vinous fermentation. When a mucilaginous, or gummy matter abounds, vinegar is formed, and the process is then termed the acetous fermentation. Substances that have already undergone the spirituous, will, very often, pass to the acetous fermentation, particularly if kept warm, and at the same time exposed to the air. Lastly, when gluten or jelly exists in considerable quantity, as in animal matter, that kind of fermentation, termed putrefactive, is sure to take place; and the product here, that is characteristic of the kind of fermentation, is ammonia, or volatile alkali, such as the common smelling salts.

We shall in this place confine our attention to the vinous or spirituous fermentation; during which there is evolved a very considerable quantity of carbonic acid gas, or fixed air. This is the process by which we obtain spirits of all kinds, as rum, brandy, gin, &c., also every kind of wine, of cider, perry, or beer. In making any of these liquors, it is necessary that a quantity of spirit should be formed, and the process is in all alike.

Wine is made of the must or pure juice of grapes, or of the juice of other fruits diluted with sugar and water in order to dispose it to the vinous fermentation. The mixture should be kept at a heat equal to about 70° of Fahrenheit: hence the advantage of making wines in warm weather. It now soon be-

comes turbid, and air bubbles are seen to rise to the surface, which are the carbonic acid gas, or fixed air.

This air being entangled in the pulpy part of the fruit, causes part of it to rise to the surface, in the form called yeast or barm. A sediment is at the same time gradually deposited; and as the bubbles of air at top burst, and let fall the pulpy part that it was entangled in, the wine is left clear and transparent, fit for casking.

That it is carbonic acid gas, that is thus extricated during the vinous fermentation, is proved, first by holding a lighted candle, or piece of lighted paper, over the fermenting liquor, when it will be instantly extinguished; and next by half emptying a bottle of lime water in the same situation, and then shaking the remainder, which will thereby become white and turbid.

This gas, being much heavier than common air, always keeps its place over the surface of the liquor, till it rises as high as the edge of the tub or vat, and then it descends to the floor; so that, if you hold the candle only a few inches above the edge of the vat, it is not extinguished; but goes out immediately when held over the liquor, and below the top of the vat. This is the reason too why, when the vat is emptied of the liquor, the gas for some time occupies the bottom of it, so that it is unsafe for the workmen to get into it, with

a view of cleaning it. This is well known to the labourers in breweries, who never descend into the vats before they have tried the purity of the air in them by lowering a candle. If the candle is not extinguished, they know that they may descend with safety; for it is then certain that the fixed air has made its escape.

After the wine is casked, the fermentation still goes on, though in a much slower degree, and a deposition of tartar takes place. The carbonic acid gas, that is now extricated, not being able to escape, is absorbed by the liquor, and gives it its briskness, and that pleasant sharpness to the palate which it now has, instead of the flat insipid taste which all wines have when first made.

The same slow fermentation, accompanied with a deposition of tartar, and formation of carbonic acid gas, continues even after the wine is in bottles, and occasions the difference between old and new wine.

In some liquors the fermentation, and consequent formation of carbonic acid gas, is much more considerable than in others, as in Champaign wine, in perry, or in cider; and hence their sparkling appearance and effervescence, when uncorked. The quantity of gas formed in these cases is so great as only to be retained in combination with the liquor under great pressure; and this pressure being removed by uncorking the bottle, part of the carbonic acid immediately assumes its gaseous form, and flies off.

As the briskness of all wines depends upon the presence of carbonic acid, they will always prove flat and insipid, either when the fermentation is so moderate, that sufficient carbonic acid is not formed, or when that, that is formed, is allowed to escape. The former case never occurs when the saccharine matter sufficiently abounds, and attention is paid to keep the liquor sufficiently warm. When, from want of this, it has happened, the fermentation must be promoted by adding more sugar, and a small quantity of yeast.

Wines are more frequently flat in consequence of the gas being allowed to escape when formed, and this both in the casked and bottled state. The same may be said of other liquors, as cider, perry, and more particularly beer. The casks should always be filled, or very nearly so, and the tighter they are the better. The greater the resistance that is afforded to the new formed gas, the more will be absorbed by the liquor, and the pleasanter it will be to the palate. In consequence of its being necessary to make an opening to let in air when a barrel is tapped, the carbonic acid gas is allowed to escape, and the beer or other liquor soon becomes flat, particularly if the orifice is not closed.

Beer, that is thus rendered flat, may be made much more palatable again, by impregnating it with carbonic acid gas. An easy mode of doing this in the barrel might, perhaps, be contrived; but for

small quantities to be impregnated, as it is required for the table, nothing will answer better than an apparatus called Nooth's apparatus, for making Seltzer water, which will presently be noticed.

In bottling every kind of wine, cider, beer, &c., great care should be paid to the corking. The gas, as it is formed, exerts great force to escape; and if the cork does not fit very accurately will be sure to make its way out. The liquor will then never acquire the briskness, and sharp taste, that it ought to have.

It is always better to lay bottled liquor on the sides than upright, for then the gas must pass through the liquor before it can escape; and besides this, the cork is kept wet and swelled, and is much less liable to decay, which would thus communicate an unpleasant taste to the liquor.

To make *beer*, barley is soaked in water, and then laid in heaps some inches deep, till the grain has germinated, and the germe, or new shoot, is about two thirds of the length of the grain. It is then dried, to stop its growth, generally by artificial heat in kilns, when it is called kiln-dried; and sometimes in chambers, where the air is freely admitted, when it is called air-dried malt.

The malt previously skreened, that is separated from the husk and germe, or new shoot, which is called its culm, and then ground, is infused in



boiling water in a mashi tub. The liquor, then drained off, is called sweet wort.

It is next boiled with hops, to give it a pleasant flavour, and is cooled as speedily as possible, to prevent its running into the acetous fermentation, and turning sour. When cooled, it is put into large tubs or vats, and brought into the vinous fermentation, by the addition of yeast.

The same circumstances take place as to the extrication of carbonic acid gas, when beer is in a state of fermentation, as when wine is made. In both it is the vinous fermentation, and in both the result is a spirituous liquor.

The barley is first made to vegetate, because it thereby acquires a greater quantity of saccharine matter; and this is a requisite ingredient in every case of vinous fermentation.

As in every case of this fermentation, called the spirituous or vinous, there is a spirituous liquor formed, we may always procure the spirit separate, by distilling such fermented liquor; and, according to the materials made use of, we obtain different kinds of *spirit*, having different flavours, as well as different names.

From wine lees is obtained the Rhenish brandy. French brandy from the husks and stalks of grapes fermented. Rum from the sugar-cane. Gin, whisky, and other British spirits, from malt.

Carrots, beet-root, potatoes, and some other

roots, by being similarly fermented, have been made to afford spirits. And amongst the Tartars a spirituous liquor, called kounifs, is made by fermenting mare's milk.

Besides being extricated during fermentation, carbonic acid gas is formed in many instances of *combustion*. As most inflammable bodies contain carbon, so most afford carbonic acid, when burnt, by the union of this carbon with the oxygen of the air. When charcoal is burnt, it is formed in such quantity, as to be made sensible by its baneful effects.

We have before stated, that it will not support life; and many a person has been killed by not being aware of this circumstance, and that it is given out, wherever charcoal is burnt.

It is very common to light a charcoal fire in cellars, and vaults, when wine is to be bottled off in cold weather; and in such situations there being no current of air to waft away the noxious gas, many have experienced its deleterious effects. In warming and airing damp or cold rooms it is frequently burnt, and in many manufactories the workmen are a good deal exposed to the effluvia. In these, and in all other cases, where burning charcoal is used, great caution should be taken, to remove the gas as effectually as possible, and for the workmen to be as little exposed to it.

The first effects that are experienced by a person

exposed to this gas, are extreme lassitude and drowsiness. He soon becomes unable to support himself, and faints away. If he has not the power to remove from the effluvia, when he first feels its influence, and is not fortunately removed shortly after he faints, he remains senseless, and is soon irrecoverably lost.

When a person is discovered suffering from this cause, he should instantly be removed to the open air, and the same plan be adopted as in cases of apparent death from drowning. If the person shows any signs of life, as soon as brought into the air, the preserving a free circulation of air, and the dashing of cold water on the surface of the body, to excite the action of the respiratory organs, will be sufficient.

But, if he appears lifeless, artificial respiration with the double bellows, continued friction, and the application of heat, must be had recourse to. If an electrical machine be at hand, a shock should be passed through the region of the heart.

Bleeding, the use of emetics, and the administration of tobacco glysters, as recommended by some physicians; I look upon not only as unserviceable, but as likely to destroy what small spark of life may yet remain.

We have said, that carbonic acid gas is given out by the *respiration of animals*, as well as by combustion. This is easily proved by breathing through

lime water; for it immediately becomes turbid, which we have before stated to be one of the properties, and a distinguishing property, of carbonic acid gas. The cause of it we shall give presently.

This extrication of carbonic acid gas in breathing is another cause, to be added to that of the absorption of oxygen, or the pure part of the air, why animals can live only a short time when confined in close vessels, and why we so constantly require the access of fresh air.

From the greater specific gravity of carbonic acid gas, it is frequently found occupying pits, and low situations. It often occupies the bottom of wells, and therefore workmen ought always to be cautioned against descending into such places, without first lowering a lighted candle. If the candle continues to burn, they may descend with safety; but if not, it is sure to be dangerous.

There are several caves and grottoes, in different countries, that are occupied, at least near their bottoms, by this heavy gas. A man may often walk in them without any ill effects; whilst a dog, or other animal, breathing a stratum of air nearer to the ground, will soon experience unpleasant symptoms.

In mines this gas is called the *choak-damp*, as inflammable air is called the *fire-damp*. A lighted candle is a sufficient test, to determine the presence or absence of the *choak-damp*: but, for reasons



before mentioned, it would be attended with great danger, where the fire-damp is present.

In all cases where the presence of fixed air is likely to be attended with inconvenience, the following rules should be observed to obviate it.

Where it can be done, it should be removed by ventilation. In rooms where charcoal is burnt, fresh air should be freely admitted. In mines, fires should be kept up near one entrance, so as to cause a constant current of air through the mine; and, where it is practicable, a stream of water should be made to flow through that part that is most charged with the gas; for water will absorb a considerable quantity of it.

The plan that is most frequently applicable for removing this baneful gas, is to absorb it by means of lime. In apartments where it is present, tubs of water with a quantity of quick lime in it will be sufficient. In wells the same mode will answer; and, in mines, pits or pools of water may be impregnated with lime, and quick lime may be sprinkled about the floors.

*Springs of water* are sometimes met with, naturally impregnated with carbonic acid gas, as that of Seltzer, which is noted for its medical virtues. To imitate such natural waters, we have only to pour diluted sulphuric acid on powdered chalk, and suffer the gas, that is extricated, to pass repeatedly through water, till a sufficient quantity is absorbed.



An apparatus, known by the name of Nooth's apparatus, effects this purpose with great ease; and, when properly managed, without much danger of its breaking. When the mixture of the acid and chalk is carelessly made, there is so much gas suddenly evolved, as frequently to burst the vessel, and inconvenience the operator. The way to prevent this accident, and the proper mode of managing the mixture is this. First put your acid in, and by inclining the apparatus, let it remain on one side; then drop in the powdered chalk, so as to occupy the other side of the vessel; and always let it stand a little inclined. Now, when you wish more gas to be evolved, you have only to shake it gently, so as to wash down a little of the chalk with the acid, and then return the vessel to its inclined position. By this means the evolution of gas will be gradual; and all danger of the apparatus bursting be obviated.

This Seltzer water, whether natural or artificial, is drunk with advantage in many cases of indigestion, and in calculous or gravelly complaints.

Water impregnated with carbonic acid gas is enabled to dissolve more lime than common water; and water thus charged deposits its redundant lime, when by exposure to the atmosphere it loses its carbonic acid gas. This is the cause of all the calcareous incrustations, termed petrifications, and all the stalactites formed in caverns.

The water in such situations, being impregnated with fixed air, dissolves more lime than it can afterwards hold in solution, when by exposure to the atmosphere it loses its air. As the water loses its fixed air, therefore, it gradually deposits its lime; and if there happens to be moss or any other substance in the stream, it becomes incrusted with the lime, whilst it retains its natural form.

Carbonic acid, like other acids, enters into combination with the *earths*, and *alkalies*, forming neutral salts. When united to lime, it forms chalk, or lime-stone, or marble; and these substances, when again deprived of the carbonic acid, are reduced to lime. For the purposes of making mortar, lime-stone is deprived of its carbonic acid by heat; the stone and some kind of fuel being burnt together in a kiln. The carbonic acid gas being thus driven off by heat, leaves the stone in the state called quick lime, which is a caustic corroding substance.

When exposed to the air, it gradually attracts the carbonic acid gas, which is always present in a small proportion, and is thus reconverted into chalk or lime-stone. It is now mild, and inert, instead of being caustic, and is no longer fit for making mortar.

The extrication of carbonic acid gas, when lime is burnt, makes it a very unhealthy employment to be engaged constantly in lime-kilns; and many ac-

cidents have happened, from persons sleeping too near the burning lime.

It is the great disposition that lime has to unite with this gas, that causes the turbid appearance in lime-water, when exposed to the gas. Lime by itself is soluble in water, but chalk is not; when therefore the lime in the lime-water has attracted the carbonic acid gas, and thus become chalk, it is deposited, and causes the turbid appearance.

As the lime will gradually attract the gas from the air, lime-water should always be kept in bottles well corked, otherwise the lime is separated, as appears by the pellicle on its surface, and the lime-water becomes only common water.

We have now finished the consideration of carbonic acid gas, and shall in the next essay treat of other combinations of carbon.

## ESSAY XIII.

### CARBON, OR CHARCOAL: COALS, OILS.

THE compounds remaining to be noticed, which have carbon for their principal ingredient, are coals of different kinds, and oils. The bitumen of coals, as well as oils, is a compound of carbon and hydrogen, with a small proportion of oxygen, and sometimes of azote. The foot, which they afford, is chiefly carbon; and the more slowly or incompletely they are burnt, the more foot they afford. That from oils forms lamp-black.

Whatever be the origin of COAL, whether vegetable, animal, or mineral, and how numerous soever its varieties, it has certain uniform characters; and differs but little in its chymical qualities.

Coal is a compound of oily or bituminous matter and sulphur with an earthy base, generally aluminous, argillaceous, or clayey, which are synonymous terms. It is a kind of schistus impregnated with bitumen and sulphur. And this schistus is found thus impregnated in various degrees.

It is only when it contains so much bitumen, as to make it burn with facility, that we denominate it coal; but in the same mountains, that we find

coal in, are other strata of the schistus less impregnated with bitumen, and these are known under other names.

Coals are commonly found in hilly situations, and always under strata of grit, which is a mixture of sand and clay; or under schistus, which is clay hardened, and splitting into layers, forming either slates, or a substance called shivers, according to its fracture.

The coal is found in these mountains in strata, from a few inches to some feet in thickness, and alternating with strata of grit or schistus. The beds of coal run in various directions, generally with a dip or inclination from the horizontal position. They are frequently intercepted by columns of other matter; and the continuation of the bed may be either higher, or lower, than the part from which it has been, or seems to have been, separated. The continuation too sometimes takes the same, sometimes a very different degree of inclination, or dip.

It generally happens that the first stratum of coals, that we come to, is not worth working, either from the inferior quality of the coal, it containing too little bitumen, or from the stratum being of too little depth.

From the degree and direction of the dip, and the level of the country, much information is to be obtained, concerning the proper place for opening the



pit. A variety of circumstances require to be taken into consideration, to work a coal mine to the greatest advantage; or to determine, whether a mine ought to be worked at all. Even in countries, or in those parts of the country, where none has been found, very probable conjectures may be formed concerning its presence, by attending to the soil, to the general appearance of the country, and to the kind of clay, sand, or other earth, that is found, when the soil is removed. There are certain appearances that indicate its presence, its value, its extent; and others, that point out the proper mode of working the mines, when discovered. These indications are subject to variations; and these variations are often appreciable by certain other rules. The business of mining is therefore an intricate art; and none ought to enter upon it, without a practical knowledge of it, or the assistance of practical miners.

When a stratum of coals is come to, that is considered worth the working, it is dug out from the superior and inferior strata, which are generally grit, or schistus, and which are then termed the roof, and floor. In doing this, care is always taken to leave columns of the coal standing here and there, sufficient to support the roof. When the roof is shivery, it is frequently necessary to support it with a roof of timber. These means being taken to support the superior stratum, the miners proceed to

very considerable distances from the original pits; and occasionally new shafts or pits are sunk, to facilitate the removal of the coals, and to afford a proper ventilation in the mines.

The *varieties* of coal have been very differently arranged by different authors; some dividing them according to their external appearances; some as to the situations in which they are found; others according to the manner of their burning; and still others as to the peculiarity of their fracture.

The fact is, that almost every mine affords a coal, differing in some respects from that of others; and, although the inland coal is generally very different from the Newcastle, which we call sea-coal, yet both vary so much, as procured from different mines, or even different parts of the same mine, that one parcel of inland or of sea-coal shall differ very considerably from another, both in its burning, and its general appearances.

The different manner in which coals burn deserves notice; and, if any arrangement of the varieties of coal is to be made, this affords the best grounds for it.

The difference does not depend wholly upon the proportion of bitumen, but partly upon the kind, whether it is more or less volatile, and whether it is more or less easily separated from the earthy base. As the coal varies in these respects, it comes under,

or approaches to, more or less, one of the following divisions.

The first includes such coal as affords a very considerable flame, and burns with so much rapidity, as only to require being lighted, like a candle, to continue its combustion. This contains most bitumen. The candle or cannel-coal is of this kind.

The second, which includes most of the inland coals, called by some split coal, contains such as burn with more or less flame, but require to be kept in a state of ignition by surrounding fuel, and leave a larger quantity of ashes, having more of the schistus in their composition.

The third division includes those coals that unite or cake together when heated, in consequence of the extrication of their bitumen. Of this kind are the sea or Newcastle-coals. This property of caking does not seem to depend upon the proportion of the bitumen, but upon its being extricated by a less degree of heat, than is sufficient to inflame it; for coals of this kind often afford as much ashes as the inland coals.

The last division contains what is called blind coal, which affords neither flame nor smoke, but when kindled makes a brisk and clear fire like coke. The Kilkenny coal is of this sort. In its external appearance it sometimes resembles the cannel-coal, and sometimes the split or inland coal. The peculiarity of this kind seems to depend upon its pos-

possessing a less inflammable bitumen, or to speak more correctly, a less volatile bitumen; for, as flame is nothing but the inflammable body ignited in a state of vapour, the quantity of flame must depend chiefly on the volatility of the substance.

When coal is piled up, ignited, and the fire then smothered, as in making charcoal, the result is a light porous substance, called COKE, which burns much like charcoal without flame or smoke. It is used in drying malt, and other operations, where the flame and smoke would be injurious. In some places furnaces or ovens are built for making coke, and the fires are put out by dampers, when it is sufficiently burnt. In this operation the more volatile, oily, or bituminous matter is exhaled, and, if collected, as in some manufactories is the case, it forms a very excellent tar. It is the caking coal that makes the best coke, for it is necessary that the pieces should be at first small, that the heat may extricate the bitumen without consuming it; and that it should afterwards run together into larger masses, that it may be left porous and spongy.

At Newcastle, the coal dust, that is too small for common use, is burnt into coke, and forms excellent fuel. Might not the coal dust in inland mines, which will not answer for making coke, be worked up into combustible bricks with a small proportion of clay, and, if requisite, a small quantity of some inflammable substance, as the coal-tar, so as to



make a neat and perhaps economical fuel for our open fire-places?

With respect to the *origin of coals*, the most probable supposition is this. That the trees and other vegetables, that are carried down the streams into the ocean, are collected in strata at the bottom, together with the immense quantity of sea weeds, that grow there, and perhaps the sea animals too. That they are afterwards covered with clay or sand; and, undergoing a gradual decomposition, form so many strata of coal, placed alternately with strata of clay or sand.

That the coal itself is of vegetable origin, is fairly inferred from a variety of vegetable remains and impressions, that are found both in the strata of coal, and in the earthy strata above and below them. That it is of submarine origin, also appears from the presence of shells, and other productions of the ocean.

The popular opinion, that coals grow like vegetables, so that the mines, that are worked out, may be opened, and worked again after a series of years, is too erroneous to need any formal refutation.

We need not, however, be alarmed for the wants of future generations, as to this useful article. The immense beds of coal yet untouched, will supply many thousands of generations to come; and there is no doubt but the same process, that produced what we at present use, is still continued, and that some future convulsions will bring to light new coal



mountains, perhaps from the bottom of the sea; for that, it is most probable, is the place where nature has fixed her laboratory for preparing this fuel for far distant ages.

OILS are a well known vegetable production. They are either fixed, or volatile; the former containing mucilage, and the latter an aroma, which is different in every different oil. They are obtained either by expression, as the olive oil, and linseed oil, among the fixed; and the oil of lemons among the volatile kind; or they are obtained by distillation, as the oil of peppermint, of thyme, and indeed most of the volatile oils.

When the fixed oils are exposed to the air, they absorb oxygen, and become rancid. The oxygen in this case unites with the mucilage of the oil; and therefore such as are deprived of their mucilage are not liable to become rancid.

The seed of the flax, from which linseed oil is obtained, contains so much mucilage, that it is necessary to torrefy or roast it, previously to expressing the oil. This destroys the mucilage, and hence linseed oil hardly ever turns rancid.

If oil of almonds is well agitated with water, its mucilage is partly separated, and the oil is less subject to become rancid.

Although oils, that are deprived of their mucilage, do not attract oxygen from the air, and consequently do not turn rancid, yet they may be made

to unite with it in other ways, and then they become *drying oils*.

Drying oil is generally made by the painters, by boiling a calx of lead, as the litharge, in linseed oil. The oil attracts the oxygen from the metal, and thus becomes a drying oil. If an oil is used that contains mucilage, the latter is separated in boiling, and swims at the top; but, such as contains no mucilage, makes the best drying oil.

When the volatile oils are exposed to the air, instead of becoming rancid, they become thick, and resinous, and lose their aroma. This also arises from the absorption of oxygen; and the same effect is produced by forming the combination in other ways, as by adding an acid to the oil.

The uses of all the oils are too well known to require enumeration.

Tallow and fat, which are animal oils, differ from the vegetable oils principally in containing a peculiar acid, called the sebacic acid.

## ESSAY XIV.

## PHOSPHORUS.

PHOSPHORUS is one of the chymical elements. It is a solid substance, but so soft as to be easily scraped or cut with a knife. It is generally of a flesh colour; and when pure it is transparent. In the air it emits a white smoke, a peculiar smell, and a beautiful though faint light, which becomes visible in the dark. It inflames by the application of a gentle heat, and then burns with a very brilliant flame.

This curious substance is of animal origin. It exists in a compound state in all kinds of bones, and likewise in considerable quantity in urine. The means of obtaining it from either are not very simple, and the process cannot be well understood until we have treated more at length of its properties.

If any device is traced with a stick of phosphorus on paper, as with a crayon, every line becomes beautifully luminous in the dark, and continues so for some minutes. If held before the fire for a moment the brilliancy is increased; but this must be done with caution, as very little heat is required

to inflame the phosphorus, and then the paper will take fire.

By handling the phosphorus, part of it adheres to the fingers, and covers them with the same light. This is not at all dangerous, as no sensible heat is emitted; but if you rub your hand much, with a view of getting rid of it, the heat excited by the friction will inflame the phosphorus; and if there is much of it, it will then burn the hand. I have observed great inconvenience from persons getting small pieces of the phosphorus under their nails, by handling it injudiciously; for, when they have approached the fire to warm their hands, such pieces have inflamed and given great pain.

To prove how easily phosphorus is made to burn, rub it on a piece of tow, wrap this tow round a Florence-flask, or other glass vessel, and pour hot water into it. The heat of the water will instantly inflame the phosphorus and the tow on the outside.

Phosphorus is soluble in oils, particularly the volatile oils, which it renders luminous like itself. This solution may, without danger, be rubbed about the face and hands, so as to render them luminous. The solution of phosphorus in ether when thrown upon boiling water, exhibits a pleasing appearance; the heat inflaming the phosphorus, and rendering it beautifully bright. This solution is also luminous of itself.

Phosphorus is likewise soluble in hydrogenous gas, or inflammable air, which it renders luminous. This very amusing compound may be obtained by boiling a little phosphorus in a solution of pure potash. The water is decomposed in this experiment, and affords the inflammable air. The retort should be very nearly filled with the solution, otherwise the gas will inflame, and diminishing the volume of air in the retort, occasion the water to rush in from the trough.

When this phosphorated hydrogenous gas is in contact with common air it emits light, and, like phosphorus itself, undergoes a slow combustion; but when it is mixed with pure air, (oxygenous gas) it immediately detonates.

To make the phosphoric match bottles, nothing more is necessary than to drop small pieces of dry phosphorus into a common phial, gently to heat it till it melts, and then turn the bottle round that it may adhere to the sides. The phial should be closely corked, and when used, the match (a common brimstone match) is to be introduced, and rubbed against the sides of the phial. It thus acquires a portion of phosphorus, which inflames on being brought into the air.

When phosphorus is consumed either by the slow combustion, that spontaneously takes place when it is exposed to the air, or by the more rapid one produced by inflaming it, the pure part of the



air (oxygen) combines with the phosphorus, and forms phosphoric acid.

This acid, like others, unites with the simple earths and alkalies, forming neutral salts. It is the compound resulting from its union with lime that forms the hard osseous matter, that is the basis of all bones. The urine contains this acid, united both to lime and to the alkalies.

After being made acquainted with these facts, we shall more easily comprehend the nature of the processes, by which phosphorus is obtained.

To obtain it from bones, select the hardest; burn and then pulverise them. To this powder add half its weight of vitriolic acid, stir it well, and then leave it for two or three days; afterwards add water gradually, and stir the mixture; when the powder has subsided, decant the supernatant liquor, and evaporate it to dryness. Upon this dry extract pour boiling water as long as it continues to tinge the water, and then evaporate this solution to the consistence of a thick sirup. To this extract add just sufficient water to dissolve the phosphoric acid, and filter through linen. Lastly, mix this extract with powdered charcoal, and distil from an earthen retort, the neck of which is immersed in water. The phosphorus will drop into the water, and may be worked into form with the fingers. Some prefer converting the phosphoric acid into a glass, which is done by exposing

the extract in a crucible to a strong heat. To obtain phosphorus from this glass, nothing more is necessary than to powder it; mix it with an equal quantity of powdered charcoal, and distil.

The sulphuric acid in this process combines with the lime, and detaches the phosphoric acid, which, when mixed with the charcoal, is likewise decomposed; its oxygen uniting with the carbon, forms carbonic acid gas, or fixed air, whilst the phosphorus comes over in its pure state.

To obtain phosphorus from urine, it is generally recommended to evaporate the urine, and then distil with charcoal; but a less troublesome, and less disagreeable way is, to add a solution of lead in muriatic acid to fresh urine, until it causes no more sediment to fall; then filter the whole through two or three folds of linen, and mix up the sediment, that is left on the filter, with powdered charcoal into a paste. This paste distilled in an earthen retort, with a pretty strong heat, affords the phosphorus.

The muriatic acid here disengages the phosphoric from both the lime and the soda, with which it was combined, and the sediment is a phosphat of lead which is afterwards decomposed by the charcoal.

It is here that I shall notice what may be termed NATURAL PHOSPHORI; by which I mean such bodies as naturally emit light, similar to that, and regulated nearly by the same laws as that of phosph.

phorus. They will include living animals, that possess this property, dead animal matter, and decayed vegetables.

Of living animals, that appear luminous in the dark, there are in this country two land insects; and on our coast several marine insects and fishes.

The two land insects are both vulgarly called glow-worms, but are very different both in their manners and appearance. The one is a scolopendra (*scolopendra electrica*), something like the centipede, being a thin and flattish worm with a great number of feet. It is often found in houses about old furniture.

The other is a soft, broad, and flat insect, something like the millepe (the woodlouse or old-fow), extended and flattened. It is apterous, or without wings, but is the female of a winged insect of the beetle tribe (*lampyris noctiluca*). The insect is very common on the heaths in Norfolk, and in similar situations elsewhere. The light emitted by this insect proceeds from the three last rings of the abdomen, is of a beautiful sulphur colour, and appears, when accurately examined, to proceed from distinct but numerous small globules within the abdomen, which are probably the ova or eggs. It is a subject worthy of further attention from the naturalist.

The marine insects will be noticed in treating of the luminous appearances of the sea, which will fall presently to be considered.

In other countries, particularly in warm climates, there are several luminous insects, and much larger ones than we have here. Such are the lantern-fly of China, and the candle-fly or fire-fly of the West Indies, which emit a very strong light from the proboscis or snout.

Of dead animal matter almost every kind has at times been observed to be luminous, as whole joints of mutton, and venison, pieces of veal-bones, lobsters claws, &c.; but what peculiar circumstances determine these substances to emit light at one time, and not at another, have hitherto eluded our inquiries; for, although they never shine, but when in a state of putrefaction, they more frequently pass through the whole putrefactive process without assuming this appearance.

There are other substances that constantly shine, when in a certain stage of putrefaction. These are various kinds of fish, as mackerel, herrings, whittings, and some others, which will be noticed in considering the cause of the brightness of the sea.

In the vegetable world, rotten wood, when in that light spongy state called touchwood, is the most remarkable. This requires moisture to emit its phosphoric light. It is yet uncertain, whether the access of air is necessary to support the light. Boyle says, that it ceased to shine in an exhausted receiver; but Achard, a French chymist, asserts that it continued to emit light in that situation. When



it becomes quite dry; its light is extinguished, but reappears, when the wood is moistened.

The colour of the light in all these instances is pale blue, exactly resembling that of phosphorus. It is in all cases, except that of the rotten wood, increased and rendered more intense by immersing the luminous body in oxygen gas, and is extinguished by immersion in azotic, or in nitrous gas. It is in all cases too, except that of the wood, attended with the extrication of an oily matter, which adheres to the fingers, and makes them appear luminous. Which circumstances tend strongly to support the opinion, that the light is emitted in consequence of the formation of a phosphorated oil, or solution of phosphorus in animal oil.

The opinion of some modern chymists is, that the light is a constituent part of the fish, but the necessity of the presence of oxygen gas makes it much more probable that the fixation of oxygen, with the consequent separation of its light and heat, is the true cause of its appearance. We acknowledge this to be the source of light in common combustion, and in the slow combustion of phosphorus; why then look for any other in the instance before us, where the presence of oxygen gas is equally necessary? Some have doubted, whether oxygen gas is necessary to the emission of light from phosphorus; but this I satisfactorily proved to be the case by the following experiment. A piece of



phosphorus being inflamed in a jar of common air, inverted over water, burnt readily, till nearly all the oxygen gas was consumed. The same piece, being again inflamed in the same situation, burnt for a few moments longer, and so a third time. Even after this the phosphorus shone for a few hours, but at length its light was wholly extinguished. After some hours, the phosphorus still remaining dark, fresh air was admitted into the jar, and the light immediately reappeared.

In rotten wood, that is luminous, as moisture seems necessary, and oxygen gas not so, a different process, not yet ascertained, is probably the cause of the phænomenon.

As the luminous appearance of the sea has frequently attracted the notice of navigators; and as, in consequence of its assuming a variety of appearances, it has been very differently explained; I shall enter more into detail upon this point, and beg leave to do it in the words of a dissertation which I wrote several years ago.

DISSERTATION *on the* LUMINOUS APPEAR-  
ANCE *of the* SEA, *read before the Natural History*  
*Society of Edinburgh, in December, 1796.*

The luminous appearance of the sea is so common, as well as curious a phænomenon, that almost

every one, who has been on the sea in a summer's evening, particularly in warm climates, must have observed it.

Its variety of appearances has however given rise to such different descriptions, and contrariety of opinions respecting its cause, that on a slight view it appears almost impossible to reconcile these various accounts, and ascertain its real nature. To attempt this, however, is the object of the present paper.

That celebrated philosopher Boyle did not let this curious phænomenon escape his extensive researches into the operations of nature. But, learning from some, that the sea was only luminous when disturbed and agitated; from others, that they had seen the whole surface of the sea covered with a bright light, like burning sulphur, as far as their view extended; whilst others again described the light, as being confined to certain parts of the surface, other parts, not far distant, being not at all luminous; he was so confounded with these various accounts, that he concludes by referring the phænomenon to some cosmical law, or custom of the terrestrial globe.

Father Bourzes in his voyage to the Indies, in 1704, says, that he could sometimes distinguish in the wake of the ship the particles, that were luminous, from those, that were not so. Some, he says, were like points of light, others like stars;

some like globes of a line or two in diameter, and others as large as a man's hand.

Sometimes all these different figures were visible together; and at other times there were what he calls vortices of light, appearing and then disappearing, like flashes of lightning. Not only the wake of the ship produced this light, but fishes also in swimming left a luminous track behind them, so that their size and shape might easily be distinguished. He remarks too, that this appearance is greatest when the water is *fattest and fullest of foam*.

In these observations are I think described all the appearances that have been observed, and noticed by others. And, I think, that they may be reduced to two kinds, which differ essentially not only in the appearance of the light, but also, as I shall afterwards endeavour to show, in their causes.

The first kind includes those cases, where the surface of the water appears luminous without agitation; and where, when agitation is necessary, to produce a luminous appearance in the body of the water, the part illuminated assumes no determinate figure, but gives out its phosphorescency wherever the agitating cause presides. Of this kind are the expanded lights mentioned by Boyle, and the luminous track left by the fish in swimming, as described by father Bourzes.

The second division includes all cases, where the light is of a determinate figure, and where it ap-

pears and disappears repeatedly without any apparent cause. In most of these cases agitation will produce the light, though it is not always necessary.

Of this kind are the beautiful scintillations observed by every mariner, and met with more frequently than any other species, in our own latitude in the summer season; and likewise the stars and globes of light mentioned in the narration of modern navigators.

Let us now proceed to investigate the cause of this phænomenon. The Abbé Nollet and several others, having examined the sea water near Venice, which in the dark was seen to contain luminous spots when agitated, thought they found small insects, to which they attributed the light.

M. le Roi, examining some water which possessed the same property, was persuaded that it was not entirely owing to insects; for the luminous spots, which he took up, were round substances of the size of pins' heads, which had no appearance of being animals.

M. Dagelet too observed similar bright bodies, which he suspected to be the spawn of some kind of fish.

M. Canton, from some experiments which he performed, and which we shall have occasion to mention presently, attributes the light of the sea to putrid fish.

Count Gregorius Razamoufsky ascribes the light,

which is observed in the ship's wake, to phosphoric gas, disengaged by the friction of the waves against the sides of the vessel.

Mr. White supposes that it is sometimes owing to large fish having the property of shining whilst alive; but, as this property is generally confined to the smaller animals, it was probably owing in the instances, to which he alludes, to the small parasitical insects, that burrow under the scales of fish, and which possess this phosphorescent quality. I have often seen these little animals burrowing under the laminæ of oyster shells.

From the above observations, it appears that the light in the sea is sometimes derived from living, and sometimes from dead and putrid animals. For reasons, which I shall give presently, I suspect that our first kind of luminous appearances is always owing to putrid fish, and the second to living animals, under which I include the spawn of fish. Let us now consider these causes separately.

That putrid fish will not only shine itself, but communicate this property to sea water, or a solution of common salt in water, was, I believe, first observed by Dr. Beal, in 1665; but Canton first made experiments with a view of ascertaining its cause.

The appearances in these experiments are so similar to those observed in the sea, which we have



included in our first division, that I am induced to attribute them to the same cause.

M. Canton immersed a herring, which appeared very bright in a darkened chamber, into salt water, and the surface of the water became instantly luminous; the light too was increased by agitation.

When he repeated the experiments with whittings, instead of herrings, he remarks, that the water did not appear luminous, unless when agitated, but that when a stick was drawn through the water, it left a luminous track behind it. I have observed the same when mackerel are used. This difference between the herring and the whiting is a curious fact, but what I cannot satisfactorily explain\*.

That the light given out by dead fish is owing to the changes it undergoes during putrefaction, may, I think, be fairly deduced from the following experiments. Mr. Canton immersed a whiting (fresh caught) in sea water, and it gave no light, till the next day.

I have observed that herrings emit very little, if any, light, till about twenty-four hours after death†: and a mackerel, which I did not procure till a day after it was caught, shone very little;

\* May it not depend upon the oily matter of the herring being specifically lighter than the water, and therefore swimming on the surface, whilst that of the whiting, being nearly the same with it, is suspended in the body of the water?

† Herrings, and, I believe, mackerel, shine considerably when swimming in the water, but cease to do so when first killed.

but the light of this, as well as of the herrings, continued to increase till sixty or seventy hours after death. The tail, fins, and head always shine first, and have generally ceased to shine, before the more fleshy parts attain their greatest lustre. Generally, by the end of the fourth day, the whole has ceased to emit light. Mr. Canton kept a whiting in a strong brine for three days, and it did not shine; when he took it out it was quite fresh.

I immersed a piece of mackerel, that shone at the time very bright, in nitrous gas, and in about five minutes it had lost its brightness, which it regained in about five minutes after it was taken out.

In the next experiment, being allowed to remain for five minutes in the gas, after its light had disappeared, it did not regain its brightness in a quarter of an hour, at which time I left the laboratory; but, on my return some hours after, it was shining nearly as bright as at first.

This effect of nitrous gas I attribute to its well-known antiseptic quality; and this, with the preceding experiments, sufficiently proves, that the fish emits this light during a certain stage of its putrefaction only.

On what the extrication of light immediately depends, it is more difficult to ascertain. From the similarity in its appearance, I think it probable, that the formation of some combination of phosphorus is the immediate cause; and from the salt water, ren-

dered luminous by fish having its surface covered with oil, and from a greasy substance adhering to the fingers; which continues to emit light after touching luminous fish, or water rendered luminous by them, I rather suspect it to be a phosphorated oil, than a gas.

We shall now proceed to consider the cause of our second division of luminous appearances, which I have before stated to arise from living bodies.

From the observations of M. le Roi and M. Dagelet, it seems to proceed in some instances from the spawn of fish: but the bright sparkling, so often observed on agitation, is more commonly owing to small insects, frequently to a species of *monoculus*, as that described by the Abbé Nollet, found in the water near Venice, and that by M. le Riville in the water near the Maldivia islands, in the East Indies.

The same, or a very similar insect, has been lately found by a friend\* of mine in the salt water of a river in Cambridgeshire, about ten or twelve miles from the sea. This gentleman procuring some of the water, which contained these luminous spots when agitated, took it into a darkened room, and dipping his hand into the water, several of the bright specks adhered to it. These he carefully took off with the point of a knife, and dropped into a glass of clear fresh water, where they continued to shine

\* Mr. William Skrimshire, a very accurate and attentive observer of nature.

for a moment. This water, when viewed in the light, was seen to contain small spherical transparent bags, which, when examined through a microscope, were found to be insects, very like the common monocus.

M. le Riville says, that the parts of the insect, that give the light, are bunches of small bodies in its posterior part, which he supposes to be the eggs. These little animals never admit light but when the water is agitated, as by the motion of a vessel, or the oars of a boat, which come out of the water every time beautifully bespangled with brilliant spots; or by throwing a stone or other body into the water, in which case many of the insects become visible.

This circumstance has induced Dr. Darwin to believe, that this kind of light is not produced by insects; but it appears to me a very inconclusive argument; for it is possible that the insects may only appear luminous when hurt or actuated by fear, which will account for their shining only when the water is disturbed; or, what is still more probable, the agitation may produce the light, by exposing the insects to the contact of the air, which may be necessary to their shining, as it is to the light of phosphorus and other phosphorescent substances.

There are several other marine animals possessing this power, which may therefore occasionally prove the cause of this phænomenon, viz. the *Medusa*

*simplex*, the phosphorical property of which was even known to Pliny; the *Dagyfa*, first discovered by Sir J. Banks and Dr. Solander, off the coast of Galicia, which, apparently, from the account given in Hawkesworth's Voyages, emits its light without the intervention of agitation; *Carcinium Opalinum*, discovered by the same gentlemen; the *Nereis Nocticula*; the *Pholas*, well known by the experiments made with them by the Bolognian academicians; the *Pennatula Phosphorea*; the *Cancer Fulgens*; and, I believe, some other species of *Medusa*.

For what purpose these marine animals are endowed with this property, has not been ascertained. The female *Lampyrus Noctiluca* (common glow-worm) possesses its shining property for the sake of attracting the male, which being a winged insect has very different habits from the female, and would otherwise have difficulty in discovering her haunts.

Another natural phænomenon which the properties of phosphorus enable us to explain is, the will-o'the-wisp, or ignis fatuus.

This luminous appearance is a blue light, often of a columnar, often of other shapes, very invariable, generally having a tremulous motion, disappearing and reappearing suddenly; and it is mostly represented as changing its situation instantaneously, and appearing in different and distant spots. It is usually met with in heathy or boggy



situations ; and there is a prevailing opinion amongst the vulgar, that it has the power of attracting and misleading travellers into bogs and miry places. The fact is, that many persons mistaking such an appearance for a light in some house, have made their way towards it, and not discovered their mistake till they were sinking in a swamp.

To a more attentive observer, these *ignes fatui* bear all the appearance of ignited vapour ; and it is now very well known to be phosphorated hydrogenous gas, or phosphorus dissolved in inflammable air, which I have before mentioned as possessing the property of being luminous in the dark.

This gas is extricated from a mixture of animal and vegetable matter, in a state of putrefaction, a circumstance that must frequently occur in marshy places.

A similar light has been frequently observed in church-yards, and been supposed by the ignorant to be something supernatural. From such a circumstance, which science teaches us to account for by natural laws, many a person has been fully persuaded that he has seen something supernatural ; and such has often been the origin of the most wonderful ghost and apparition stories.

The human mind seems prone to attribute to supernatural agents whatever is not within its reach to comprehend. It is therefore amongst men of

weak and unenlightened minds, that we find most instances of a belief in the appearance of apparitions.

But ought we not to be more humble, and acknowledge our ignorance? When we meet with a visible appearance that we cannot explain, or hear a noise that we cannot account for, would it not be more becoming in us to attribute it to some natural cause, that from our confined knowledge we are unacquainted with, than to conclude that it is inexplicable by natural laws, and must be something supernatural, because we are ignorant of its cause?

How many people are ignorant that there is a peculiar gas, often extricated from putrid matter, which burns of itself, and appears luminous in the dark! and to us, who know the fact, how absurd, how preposterous it appears, that such people should therefore attribute such an appearance to the agency of supernatural powers! It is preposterous, but surely not more so, than for us to attribute to the same powers other occurrences which we cannot explain; and yet many, whose minds are well informed, are too apt to make such an inference.

I cannot avoid bringing forward another argument against the probability of every tale or story that tends to inculcate a belief in the agency of supernatural powers in these, and similar occurrences. It is an argument that I have observed more frequently than any other to discourage such belief, and this induces me to notice it.

Is it at all probable, that the established laws of nature, laws which the Creator himself has established and ordained, should in any instance be suspended, or others appointed, unless for the effecting of some grand, some important object? Is it likely, I ask the superstitious narrator of the story, that such means should be had recourse to, for the purpose of frightening and terrifying any one? And yet such in general, if the tales were true, would seem to be the only effect, and the only object of this deviation from fixed and established laws.

Or is it probable, that such extraordinary means should be adopted, even to alarm the conscience, and to punish or reclaim an individual sinner? No, be assured the conscience of the wicked man needs no such spur to increase its poignancy. It is ever on the alert, and its sting will, without such intervention, at times be felt by the most hardened and abandoned profligate. And as to punishment, it is not in this, but in the world to come, that the deeds of the wicked will be judged, and their punishments awarded.

## ESSAY XV.

## SULPHUR, OR BRIMSTONE.

SULPHUR, or brimstone, is an inflammable substance, found alone or combined with other bodies, in a variety of situations.

In volcanic countries it is found almost pure, having been volatilized and thrown out by the volcanoes. In such situations the earth and stones, in which it abounds, are distilled, and the result of this distillation is brought to market as crude sulphur. By fusion and casting in moulds, it forms roll brimstone; and by subliming or volatilizing it with a gentle heat in close chambers, we obtain the flowers of brimstone.

Sulphur is also found in abundance in coal mines, and in the ores of different metals. In this state it bears the name of pyrites; and the copper and iron pyrites are the source of most of the sulphur used in this country. In roasting the ores to obtain the metals, much sulphur is sublimed and collected. In other cases the pyrites are piled in the form of pyramids, the sides of which are earthed up. By the addition of a small quantity of fuel the pile is lighted, and made to burn slowly, during which the sulphur is volatilized, and escaping to the top, is

there condensed, and then melted in cavities destined to receive it.

When sulphur is burnt, it combines with oxygen, and forms sulphuric acid, or oil of vitriol. In the manufacturing of this acid, about one eighth of saltpetre is added to the sulphur, to assist the combustion, by affording oxygen. The operation is performed in chambers lined with lead, and the acid vapours are condensed against the sides, or absorbed by water, with which the floor of the chamber is covered. When this water is sufficiently impregnated, it is concentrated in leaden boilers, and rectified in glass retorts, to render it white and pure.

Sulphuric acid is much used by the dyers, and in a less oxygenated or acidified state, when it is called sulphureous acid, it is used to bleach or whiten silk.

When a match is lighted, and a rose held over the vapours, its colour soon fades, and the rose becomes white. This is effected by the sulphureous acid vapours that are formed, and proves its bleaching qualities.

Sulphur united to the alkaline salts forms the different hepars, or livers of sulphur. Acids decompose these, and at the same time disengage a very offensive gas, which is inflammable air, holding sulphur in solution.

The SULPHURATED HYDROGEN GAS gives



the peculiar smell and taste to Harrowgate water. It is like that of rotten eggs, or the scourings of a gun-barrel. Notwithstanding this peculiar, and, to most people, very disagreeable flavour, Harrowgate water is soon drunk without disgust, the palate being by habit soon reconciled to it. It tarnishes silver, and blackens white paint. Characters written on paper with a solution of sugar of lead in water, are made visible, and rendered almost black, by holding the paper over fresh Harrowgate water; and still more readily by immersing it in the water. This has been had recourse to for secret correspondence, for the characters are quite invisible before the application of the water.

Many curious tales are circulated about ladies who have used white paint, being disfigured by bathing in these waters. The paint being a calx of lead (white lead) is immediately blackened by the application of the water.

Sulphur seems to be afforded by animal and vegetable putrefaction.

## ESSAY XVI.

### THE ALKALIES.

THE alkalies are divided into volatile and fixed. Ammonia is the volatile, and soda and potash are the two fixed alkalies. The latter are still considered as elementary substances, although many circumstances render it probable, that they are compounds of azote with one or other of the earths. Ammonia or the volatile alkali, it is now well ascertained, is a compound of azote (the base of impure air) and hydrogen (the base of inflammable air).

Notwithstanding its being a compound, we shall treat of ammonia, in this place, as allied in many of its properties to the fixed alkalies. Like them it changes vegetable blue colours to a green; it has an acrid taste; renders oils soluble in water; and when pure dissolves, or reduces to a jelly, wool and some other animal substances. These may be considered the general qualities of alkalies; and now let us consider each of these substances separately.

AMMONIA, or volatile alkali, in its pure state, is in the form of gas; when absorbed by water, it is the *aqua ammoniæ puræ*, sometimes used in smelling-bottles; and when rendered mild by its union

with carbonic acid or fixed air, and crystallized, it constitutes the common smelling salts.

When equal parts of sal ammoniac (muriate of ammonia) and quick lime, each in powder, are heated in a glass retort, a gas is extricated, which, if collected over mercury, retains its aeriform condition, and is the pure ammonia, or ammoniacal gas. If collected in a vessel containing water, it is immediately absorbed, and constitutes the *aqua ammoniæ puræ*, or liquid ammonia.

The gas has a pungent smell, turns red vegetable infusions to green, extinguishes flame, and is fatal to animals.

The chief uses of volatile alkali are as a medicine. It is produced by the putrefaction, or by the distillation, of almost all animal matter. It is this salt in a state of gas that gives the pungent smell, and affects the eyes, on entering stables, slaughter-houses, and similar places, that are not well cleansed.

Sal ammoniac, from which the volatile alkali is chiefly procured, is a compound of ammonia and muriatic or marine acid; hence its name in the new nomenclature is *muriate of ammonia*. This compound salt is obtained by distilling the foot, that arises from burning the dung of certain animals. It is mostly imported from Egypt, where the dung of the camel is dried in the sun, then burnt, and the foot carefully collected; from which the sal

ammoniac is procured by simple distillation. It is only the dung of such animals as feed on saline vegetables, that will afford the sal ammoniac. There is nothing peculiar in that of the camel, as has been very generally believed. It depends solely on the kind of food; and unless the animal has eaten the saline vegetables, such as grow on the sea shore, and near to it, its dung will afford no ammoniac.

There is a manufactory of sal ammoniac at Edinburgh, but the process is kept a secret.

This salt is used in some processes in the art of dyeing. It is used as a flux in foldering, and in some cases as a medicine.

The FIXED ALKALIES are of two kinds: the one called vegetable alkali, or potash; the other mineral alkali, or soda. They are both known in commerce under different names, according to the substances from which they are procured.

POTASH, or the vegetable alkali, is generally obtained from wood ashes; but sometimes from the tartar, or from the lees of wine, in which case it is called *salt of tartar*. Most of our potash is imported from the North, where wood is in sufficient abundance to allow of its being burnt for this purpose. The hard woods afford the most salt; but every vegetable, when burnt, affords some. The ashes are washed in water, which dissolves the potash; the solution is then concentrated by boiling, and evaporating in iron boilers; and the salt thus pro-

cured is sometimes heated in the fire to purify it from colouring matter.

The vegetable alkali is used in bleaching, in making soap and glass, and as a medicine. Wood ashes are frequently used in washing; in which it is the potash that proves serviceable; for by uniting with grease, and other filth, it renders them soluble in water. For the same reason salt of tartar is sometimes used to take out grease spots.

SODA, or the fossil alkali, is sometimes found in a native state, as in the lakes of Natron in Egypt, which are dry in the summer season; the water leaving, after evaporation, a bed of soda, or, as it is there called, natron, of two feet in thickness, which is dug out with iron crows, for sale. Such as is not obtained from this source, is procured from the ashes of seaweeds, and certain plants that grow on the seashore. These vegetables are thrown together in heaps, and burnt; the ashes are then collected, and treated in the same way as wood ashes for obtaining the vegetable alkali.

When it is obtained from the seaweeds, as seawrack, or tang, which are different species of fucus, the salt is called *kelp*. When obtained from a plant called *barilla*, which grows in great perfection on the Spanish coast, the salt is also called *barilla*. There are several other vegetables which afford the mineral alkali; as *salsola kali*, some of the genus *chenopodium*, and also some of the *atriplicies*.



The uses of this alkali are nearly the same with those of the vegetable alkali, but it is more used in glass-making.

The alkalies, as we usually meet with them, are in a mild state, in consequence of their combination with carbonic acid, or fixed air, which is the cause of their effervescing with acids. When boiled with quick lime, they lose the fixed air, and become caustic.

The alkalies combine with all the acids, and form neutral salts; thus, when beer is sour, a few grains of salt of tartar, or other vegetable alkali, added to a glass of the beer, will neutralize the acid, and take off the tartness.

The alkalies will all of them unite with oils, and the result of such a combination is a SOAP; the kind and quality of which depend upon the kind and quality, and also upon the proportion, of the ingredients.

The first part of the process consists in making the alkali pure or caustic by mixture with quick lime, which abstracts from it the carbonic acid or fixed air. This caustic lie, mixed with oil or tallow in due proportion, and boiled to a proper consistence, forms soap.

Boil one part of good barilla with two of quick lime in a sufficient quantity of water, strain the liquor through a cloth, and evaporate, till a phial, holding eight ounces of water, will hold eleven of

this solution ; then boil one part of the lie with two of the oil, and you will have a good hard Soap.

In manufactories, where the fuel is of material consequence, the lie is made without boiling. Equal measures of barilla and flaked quick lime are heaped up together, water is poured on the top, and filtering through the heap is caught in proper vessels ; more water is then poured on, till no salt comes with it, and the lie of different strengths is kept separately. It is now mixed with the oil and tallow in boilers, the weakest lie first, then that that is stronger, and so on ; and when boiled sufficiently the soap is made.

The best soft soap is made with five parts of potash, three of whale oil, and one of tallow.

For soaps of an inferior quality, more tallow, kitchen grease, or oil of an inferior quality, is used.

And lately the French chymists have recommended a cheap soap to be made, by using woollen rags and old woollen clothes of all kinds, locks of wool, hair, and even the horns of animals, instead of oil. These substances are all soluble in the caustic lie, and by proper boiling form a soap. The chief inconvenience of such a soap is, that it possesses a very unpleasant smell. It is however used by many of the cloth manufacturers in cleansing their stuffs ; and as they require repeated washing, the smell is thereby completely taken off.

The most delicate soap is made with olive oil; and a peculiar kind, called Starkey's soap, is made by triturating ten parts of caustic alkali hot, with eight parts of oil of turpentine, which instantly forms a very hard soap.

Another important use of the two fixed alkalies is in the manufacture of GLASS. Mixed with the siliceous or flinty earth, they form a compound that is very fusible, and according to the ingredients more or less transparent; and of such a mixture is glass of every kind manufactured.

The siliceous earth is used either in the form of sand, of flint, of quartz, or some other hard stone of this genus. Such being selected as is fittest for the particular kind of glass required.

The common green bottle glass is made of the common sand from the sea-shore, for the flint, and the soap boiler's refuse for the alkali. Both the ingredients therefore are impure, and consequently the glass is of an ordinary quality. The alkali in the soap boiler's refuse is calculated to assist the fusion of the mass very considerably, the quantity of flint renders it a very hard glass, and it derives its green colour from a portion of iron, contained in the ingredients.

The mass is fused in vessels made of Stourbridge clay, in a furnace of considerable power, and the bottles are fashioned by blowing; after which they

are immediately put into the annealing oven, and allowed to cool gradually.

Window-glass is generally made of a fine white sand, such as is found on the Norfolk coast, and is called Lynn-sand, and the soda obtained from burning the sea weeds, which is known by the name of kelp.

The kelp is previously calcined to expel the fixed air. When the mass is melted, it is run into large plates, and this operation is termed flashing.

The same kind of sand is used for what is called flint glass, but in this there is an addition of litharge, or some other preparation of lead, which, besides promoting the fusion, makes the glass to be more easily cut, and also gives it a greater polish.

The stronger the heat required to fuse the mass, in general the finer is the glass; and therefore when only a coarse glass is required, a greater quantity of flux is added.

The addition of manganese destroys the colour, that would otherwise arise from the foreign admixture of any inflammable matter; and that too, in a great measure, that arises from iron. It is therefore always used, when a colourless and transparent glass is required. It is used for instance in fine window glass.

When it is wished to give an artificial colour to glass, different substances are employed for that

purpose. The blue colour, and various shades of violet are given by the admixture of a metal, called Cobalt; and a fine green by some preparation of iron.

Quartz crystal powdered, is used instead of sand, in manufacturing a fine glass for optical instruments. Other kinds of siliceous earth are used in particular manufactories, as being either more easily procured, or more particularly adapted to the kind of glass there required.



## ESSAY XVII.

### THE EARTHS.

THE simple earths are nine in number; but several being newly discovered, and by no means generally known, and little or not at all applied to useful purposes, we shall merely mention the names by which they are designated, and pass to the consideration of such as are more interesting.

They are known by the following names: 1st, lime; 2d, magnesia; 3d, alumine; 4th, flint; 5th, barytes; 6th, strontian; 7th, jargonite; 8th, glucine; and, 9th, argilline. The four first are those that will be more particularly considered.

They are never found perfectly pure, but always blended with each other, and often with other substances. Such earths and stones however as consist chiefly, or owe their chief properties to any one of the simple earths, are classed together, and arranged as species under that particular earth, as a genus. Thus we shall commence with considering some of the various forms under which lime is found, which is called the calcareous genus.

LIME is found in most countries, and frequently in great abundance. Like the alkalies it is caustic,

when quite pure, but it is never found naturally in this state. It is generally combined with carbonic acid or fixed air, which renders it mild, and it is mostly mixed with some of the other earths.

The variety of forms, under which lime is found, may be divided into two classes, the first comprehending those irregular masses, that constitute the calcareous strata, and sometimes form whole mountains, and the second including the calcareous crystals, or spars, that are regular in their figure, and found in considerably less quantities. Both kinds effervesce with acids, and are converted into quick-lime by burning.

Of the first class, *chalk* is the softest, and apparently of the latest formation. It is found in large beds in many parts of this kingdom. When white and easily pulverisable, it is formed into what is called whiting. For this purpose the chalk is agitated in water, to separate the foreign substances, as flints, pyrites, &c.; the water is then poured off, and the chalk suffered to subside; which, when dried, is the whiting of the shops.

It has been observed, that rooms newly white-washed are unwholesome; and this has been accounted for, by supposing that the lime or chalk has the power of absorbing the pure part of the air. All the earths have been said to possess this property, but the fact is not yet decidedly ascertained. The white-washing of apartments is ne-

cessary to cleanliness, and has been very properly recommended as part of the plan, for purifying hospitals, and other buildings, from contagion; but if the preceding supposition be founded in fact, such rooms should not be used, till two or three days after the operation.

In a state harder than chalk, lime is known in some districts under the name of *clunch*, which is burnt for lime, but is inferior for that purpose to the more indurated substance called *limestone*. This is of various kinds, according to the state of induration, and the nature of the substances with which the lime is admixed. Some species are fittest for burning into quick-lime, and others for building. In general, the hardest limestones afford the best lime.

In countries, where neither chalk nor limestone is found, sea-shells, corals, and madrepores are collected from the sea shore, and burnt for lime.

When limestone is to be burnt, to expel the fixed air, and convert it into quick-lime, it is broken into small pieces, and placed on the kiln, with alternate layers of some fuel, which is generally coal; the fire is then lighted, and the mass kept in a state of ignition, till the air is all expelled, which may be known by its no longer effervescing with acids.

In this state the lime is white or grayish, it is caustic, and has a great avidity for water, by application of which it heats, bursts, and is reduced

to a fine powder. It is now called flaked lime, and when sifted, is fit for making mortar, which is done by working it up with sand, the fragments or dust of stone, cinder-ashes, or some such hard substance, and a sufficient quantity of water. Horse-hair, or chopped hay or straw, are occasionally added, to make it, as the workmen term it, more binding.

Quick-lime, whether alone or mixed up into mortar, has so strong an attraction for carbonic acid, or fixed air, that, when exposed to the air, it gradually absorbs it from the atmosphere. Hence the necessity of using lime, for making mortar, as soon as it is burnt. It seems to be by this gradual conversion of lime into limestone, that mortar hardens by age, and as it is a long time in acquiring its full quantity of fixed air, so it is a long time before it has acquired its greatest degree of hardness. It is generally observed, in pulling down very old buildings, that the mortar is as hard as the stone; and it has been inferred from thence, that the ancients possessed the art of making a much firmer cement, than what we use; but it is very probable, that its superior hardness depends upon its having acquired more fixed air from the atmosphere.

Another state, in which lime is found, is in admixture with clay and sand, when it is denominated *marl*, which, as well as limestone, is very much applied to the manuring of land.

MARL is called calcareous, argillaceous, or sandy marl, according to the proportion of lime, clay, or sand.

The first, or *calcareous marl*, is generally of a yellowish white, or yellowish gray colour, and is found a few feet under the soil on the sides of hills, or under turf in bogs. It is sometimes distinguished by the name of shell marl, when it abounds in the remains and fragments of shells, and by that of stone marl, when it is particularly hard and indurated.

*Argillaceous marl* is gray or brown, or reddish brown, or yellowish, or bluish gray. It is more unctuous or greasy to the feel, and harder than the former.

*Sandy marl* is brownish, gray, or lead coloured, and contains so much siliceous or flinty sand, that the residuum, or what is left after pouring acid upon it, will not be ductile enough to form a brick, as is the case with the other marls.

With respect to its utility in manuring land, a marl is not reckoned of any value, unless it contains thirty-five or forty per cent of lime. The easiest mode of ascertaining which, is to immerse a hundred parts of the marl, the value of which you wish to ascertain, into a sufficient quantity of diluted muriatic acid. All that is dissolved by this means, is lime, and no more of it; by weighing the remainder therefore, and subtracting it from the



whole, you ascertain the exact proportion, that a hundred parts of the marl contain.

The last form, in which the lime of this class is found, is in a state of MARBLE. This is a limestone capable of bearing a polish; it is of different degrees of hardness, and of different colours. Its surface too is diversified with veins, lines, spots, and other figures, differing in colour from the ground, and frequently containing the remains of shells, and a variety of madrepores and corals. The use of marble, as the most ornamental stone for building, for sculpture, &c. is very generally known.

There is reason for believing, that most lime-stone rocks and strata, marbles, marles, and other calcareous substances, have been originally formed by animals, and chiefly by marine animals, the exuviae of which have been gradually collected into these vast heaps, in which we now find them, and have by trituration and partial decomposition assumed their present appearance.

A strong argument in favour of this opinion is deduced from the frequent appearance of shells, bones, and other animal remains, in the different species of calcareous stones, particularly in chalk-beds, and marble quarries.

The shells of the testaceous animals consist wholly of carbonate of lime, or chalk, with more or less animal matter, and that differently disposed,

being in the porcellaneous shells, as the cypræa, &c., in much smaller proportion, than in the mother-of-pearl shells, as oysters, muscles, &c. In the former, the animal matter seems to be uniformly dispersed through the calcareous matter, as a connecting medium. In the latter, it is membranaceous, and stratified, being deposited by the animal in alternate layers with the carbonate, so that the membrane in these shells retains its form after the calcareous matter is dissolved by an acid.

The crustaceous animals, as crabs, lobsters, shrimps, and craw-fish, have their shells, consisting partly of carbonate of lime, and partly of phosphate of lime, resembling in this respect the shells of birds eggs.

From this view we can easily conceive, how the exuvixæ of these animals may form beds of chalk, and other calcareous stones, there being little more requisite, than the decomposition of the animal matter.

The second class of calcareous productions is, where the lime combined with fixed air, or with some other acid, assumes a crystallized form, in which case it is generally called SPAR.

With the carbonic acid it forms the dog-tooth spar, the columnar or pyramidal calcareous spar, according to the shape it assumes; and, when transparent, it possesses the property of double refraction as the Iceland crystal.

When combined with a peculiar acid, termed the fluoric acid, it forms Derbyshire spar, or blue John, as the miners call it, a stone much used for ornaments. It is various, and often beautiful, in its appearance, and bears an excellent polish. In ornaments of this kind, it is a practice, frequently had recourse to by the workmen, to fill up the accidental cracks and flaws with an ore of lead, or of copper, which they execute very neatly, even so as to enhance the value of them, deceiving the purchaser with the assurance that it is natural.

Lime, combined with sulphuric acid, is called GYPSUM, plaster of Paris, plaster stone, or selenite. It is very abundant in some countries. The hills near Paris are chiefly composed of it, and in some parts of America it is used as a manure, chiefly as a top dressing to grass land. When burnt or calcined, it is miscible with water, forming a liquid, which, from its suddenly drying, and becoming solid, is much used for casting ornaments, as busts, &c.

In Derbyshire, and the neighbouring counties, the plaster stone is much used for flooring. For this purpose it is first calcined, and then powdered. The powder being mixed with water to the proper consistence, is spread to the required thickness upon reed, when it immediately becomes solid.

It is this selenite, or gypsum, that generally gives to water the quality called hardness. Such water curdles soap, and is therefore unfit to wash with. The sulphuric acid of the selenite attaches itself to the alkali of the soap, whilst the oil and lime are separated in flakes, and give the appearance of curdling.

It is a common practice to add wood-ashes to hard water when it is required to use it for washing; in this case the alkali of the wood-ashes decomposes the selenite.

Hard water almost always contains carbonate of lime or chalk, as well as selenite. By boiling the water this is separated, and forms the fur or crust on the inside of tea-kettles; so that hard water is rendered somewhat softer by boiling, though not quite so. For chymical purposes this property may be wholly obviated, by adding to the water a small quantity of barytic solution.

Pease, and other greens, retain their colour better when boiled in hard, than when boiled in soft water; but they are not so soft and tender. Soft water is best adapted to most manufactures, as brewing, dyeing, &c. In dyeing, if hard water is used, the selenite, or its earthy part, is deposited in the stuff, and prevents the colouring particles from penetrating. In brewing, or any other process where water is used to extract the virtues from vegetable, or from animal matter, soft water is

best, because its solvent powers are greatest. In making tea, hard water will not extract so much as soft, unless the tea be powdered; for it has not so much the power of softening and opening the tea leaves.

Lime being evidently an animal secretion, it has become a matter of dispute, whether it is absolutely formed by animals, or only separated from the food, and deposited in the form of shells or bones in particular situations. If it could be proved that all the lime contained in the shell of the lobster, or in the shells or bones of any other animal, has not been received by the stomach with its food, it must follow, that lime is a compound, not a simple substance; whereas the chymist has not yet been able to detect its constituent parts.

It appears, however, probable from several facts, that the lime is received into the stomach, and not formed by the animal. For instance, chickens fed purposely, and with great care, on such food as contains least lime, compared with others fed in the usual way, were much more feeble, and their bones both smaller and more flexible.

Hens, also, kept carefully from lime, laid eggs without shells; but on being allowed again to pick up pieces of lime, mortar, and the like, they laid eggs covered with their natural shells. Most articles of food contain lime in small quantity. The fairest experiments might be made by keeping fishes in



distilled water, as free from animalcula as possible, either in the water or the surrounding air. Such fishes we know will live and grow with no other aliment than air and water; and if the quantity of lime in their bones, scales, and other parts, is found to be at the same time increased, it would amount to a proof that the fishes have formed the lime, and, consequently, that lime is a compound. Such experiments require to be conducted with the greatest accuracy and attention to become satisfactory.

MAGNESIA is an earth that is much less frequently met with than lime, and is never found alone. The stones in which it constitutes a considerable part, are known by a peculiar greasy feel, as the *French chalk* (a steatite), which is used to take grease spots out of silk; *lapis ollaris*, a blueish stone, so soft as to be easily cut and fashioned by a turning machine into a variety of utensils; and lastly *asbestos*, a fibrous stone, that may be spun and woven into cloth. In such a cloth, which is perfectly incombustible, did the Romans sometimes burn their dead bodies, to preserve their ashes.

Epsom salt is a combination of magnesia with sulphuric acid, and is found in a variety of natural waters. By adding an alkali to a solution of this salt in water, the magnesia is precipitated in a pure state, forming a white impalpable powder.

ALUMINE, argil, or clay, is the next earth to be considered. From its ductility when moistened, and its hardening in the fire, it is made the basis of bricks, tiles, and every kind of pottery or earthenware. It is found of various degrees of purity, and mixed with a variety of other earths; such, therefore, are selected by the manufacturers as are fittest for the purpose required; and for the nicer kinds of wares, artificial mixtures of clay and other earths are used.

A tolerably pure white clay is used for making pipes. A stiff blueish or grayish clay, with a greasy feel, is fittest for bricks and tiles, which being naturally coloured with an iron ore, turns red by burning.

To make bricks, the clay being dug, and thrown into heaps, is moistened with water, and worked by men treading it down with their feet. It is then cut again with wooden spades, thrown into heaps, and, if required, again worked with the feet. It is now carried to the brick-maker, who cuts off enough for a single brick, kneads it like dough, on a board sprinkled with sand; he then puts it into a wooden mould, previously moistened, and levels it at top. A boy then turns it out upon the ground, where it remains till it is dry, being occasionally turned. The bricks are then piled up into walls, and exposed to the air, but sheltered from the

rain, and after a few weeks are put into the kilns and burnt.

For pantiles, the same clay is used; but it is kneaded or worked very fine, generally by means of a mill contrived for the purpose.

The common stone ware is made by mixing a certain proportion of sand with the clay; and the white or Staffordshire stone ware, by mixing pipe clay and powdered flint in different proportions. The clay is well worked in water, to separate the sandy parts; and the fluid mass, containing the purer parts of the clay, is then passed through sieves. The flints are calcined and then ground, by means of a very hard stone called chert; being then sifted into water, this fluid mass is mixed with the fluid clay, and left to set. The mixture, after being dried in a kiln, is tempered till fit for turning, and in this state is used for a variety of wares.

The finest China-ware is formed by an admixture of what is called petunze, with clay. This petunze is a granite partly decomposed, found at the bottoms of certain mountains, and properly prepared.

These mixtures are made into a ductile mass with water, are well kneaded, and then fashioned by a turning machine or lathe, to the proper shape, and, lastly, baked in ovens or furnaces, heated to the degree suitable to the particular article.

The coarser kinds of pottery would be pervious to water were they not glazed, which is generally done with what is called potter's lead ore, or some other calx of lead; or, if a black glazing is required, with a mixture of white lead, and an ore called manganese. The glazing material is powdered and mixed with water, into which the vessels, previously dried by a slight baking, are dipped. The porous vessel absorbs the water, and leaves the powdered ore on the surface, which, by exposure to heat in the oven, vitrifies and forms the glazing.

The finer kinds of pottery, as the Staffordshire ware, are glazed with common salt, which, being vaporized by the heat of the oven, unites with the clay, and vitrifies the surface, and in some cases, as with Queen's-ware, the glazing is a mixture of white lead, powdered flint, and flint glass. Other kinds become semivitrified in baking without any addition, in consequence of the siliceous earth which they contain in their composition.

The glazing material of Delft-ware is glass rendered opaque by an addition of oxyde, or calx of tin.

In the manufacture of China and porcelain, after a first baking they apply the glaze, then bake to vitrify this, next paint it, and, lastly, bake again, to combine or amalgamate the paint with the glaze.

For this kind of painting the colours are all prepared from metallic substances, as best adapted to bear heat, and unite with the enamel in the last bak-

ing, which they call burning in, or fixing the colours. Gold gives a beautiful purple; iron a red; lead, antimony, and silver, yellows; copper, green; cobalt, blue; and manganese, a violet coloured paint.

Queen's-ware, the name first given to the pottery made by Wedgwood, and called often Wedgwood-ware, is superior to most others, being at the same time cheap and ornamental, and possessing the valuable properties of resisting the corroding effects of acids, and bearing a very great degree of heat.

Besides the very important uses of clay, just mentioned, it serves another as important, namely, the manuring of particular soils. How the clay is to be selected for this purpose, and to what kind of soils applied, I shall defer mentioning for the present, as I intend to treat presently of manures in general.

We shall conclude the consideration of clay, or alumine, with an account of the manufacture of alum. ALUM is a mixture of sulphate of clay and sulphate of potash; it consists, therefore, of sulphur acidified by oxygen, and combined, in the state of an acid, partly with clay and partly with potash.

It is chiefly manufactured from a stony substance, called shale, or aluminous schistus, which contains both clay and sulphur. This schistus is sometimes inflammable enough to burn by itself; but when this is not the case, some kind of fuel is added to it,



and the fire kept up some time. The sulphur thus becomes acidified, and unites with the clay, forming an efflorescence on the surface of the schistus. This is elutriated by pouring water on the heaps; and, when saturated, this water is put into leaden boilers, and evaporated. During the evaporation, potash is added to saturate the acid, which is usually predominant, and likewise to assist, which it essentially does, the crystallization of the alum. The lixivium, reduced to a proper strength, is put into coolers, and the alum is crystallized as the liquor cools.

The principal use of alum is, as a mordant or fixer of colours in dyeing and in printing on cottons. It is also used in the preparation of leather. It is added to tallow, to render it harder for the making of candles. Mixed with glue, it in a great measure prevents the depredation of insects on furniture. And the printers rub their balls with calcined alum, to make them take the ink more readily.

SILEX, or silica, the last of the simple earths that I shall mention, differs from all others, in being much harder, and insoluble in acids. Most stones, that are hard enough to strike fire with steel, are of the siliceous genus. Flints, quartz, rock-crystal, and the precious stones, are all of this kind.

The siliceous earth becomes easily fusible by addition of an alkali, and is therefore, as we before mentioned, the principal ingredient in glass. Sands of different kinds, which are the siliceous stones

broken down by exposure to the weather, to water, and to accidents, and washed away by the waters, to be deposited in beds or strata, are preferred in the manufacture of glass, because they are already in powder, and therefore fit for mixing with the other ingredients.

The simple earths, we have said before, are seldom found alone, but generally combined with each other, forming, however, an uniform mass, in consequence of their being intimately blended. In this state they are denominated stones simply, as limestone, quartz, flint, asbestos, talc, garnet, &c. But frequently these stones are mixed, several of them together, into an irregular mass, connected by a common cement, and in this case they are termed aggregate stones, as the granite, porphyry, pudding-stone, &c. These constitute what are called the primary mountains, whilst the limestone mountains, chalk-hills, and strata of sand-stone, are termed secondary, being supposed to be of later formation.

As connected with the earths, we shall now take into consideration the subject of manures, and give a slight description of the different kinds of soils.

## ESSAY XVIII.

EARTHS,  
SOILS, AND MANURES.

THE consideration of the simple earths leads us naturally to that of soils, which consist of these simple earths in different proportions; and, as intimately connected with this, we shall at the same time treat of the different substances employed as manures, and endeavour to ascertain the best rules for adapting the latter to the former.

The chief part that soils act in the growth of plants, is to support the vegetable by its roots with sufficient firmness, and to supply it with a proper quantity of water; besides which, it should contain charcoal, or coaly matter, and certain salts in small proportion.

From this it appears, that a good soil should be sufficiently porous, to allow the roots to strike freely, and to suffer the superfluous water to drain off; but, at the same time, close and compact enough, to retain the roots firm, and prevent the water draining off too fast. This is only to be obtained by a mixture of lime, clay, and flint or sand in due proportion; for these earths retain the water in very different degrees, and form soils of

very different degrees of compactness, according to their proportions.

The soils, most frequently met with, are clay, chalk, sand or gravel, clayey loam, chalky loam, sandy loam, gravelly loam, ferruginous loam, and boggy or heathy soil, or, as it is often called, mountain soil.

CLAY\* is of very different colours, white, gray, brownish red, brownish black, yellow or bluish. It feels smooth, and somewhat unctuous; if moist, it adheres to the fingers, and is ductile. If thrown into water, it gradually diffuses itself through it, and then slowly subsides. Usually it does not effervesce with acids, unless a strong heat be applied. If heated, it hardens, contracts in all its dimensions, and, if sufficiently heated, forms bricks. It consists of alumine (pure clay) and sand, with a small proportion of calx of iron, which gives it its colour. The proportion of pure clay varies from twenty to seventy-five per cent, and is separable from the sand, by boiling in strong vitriolic or sulphuric acid.

CHALK, if tolerably pure, is of a white colour, moderate consistence, and dusty surface; stains the fingers, adheres slightly to the tongue, and does not harden, but burns to lime, when heated; losing at the same time four tenths of its weight. It effe-

\* By clay in this place I do not mean argil, or alumine, the simple earth, but clayey soil, which is a compound of different earths, among which alumine is most predominant.

vesces with acids, and is dissolved almost entirely therein.

By SAND is meant small loose grains of great hardness, not cohering when wet. It is generally siliceous, and therefore insoluble in acids. *Gravel* differs from sand chiefly in the size of its particles; but calcareous stones, when small and rounded, are often comprehended under the same term.

LOAM denotes any soil moderately cohesive, that is, less so than clay, but more so than loose chalk, and consists of elay and sand, with sometimes chalk.

*Clayey loam* is that in which elay predominates, and is by farmers generally called strong, stiff, cold and heavy loam. *Chalky loam* is a mixture of clay, sand and chalk, the latter being in greater proportion, than it is ever found in clayey loam. It is also less cohesive than clayey loam. *Sandy loam*, in which sand, partly coarse and partly fine, forms from eighty to ninety per cent, is less coherent than either. *Gravelly loam* differs from the last, in containing coarser sand, and pebbles. This, with the two last soils, are termed by the farmers, light and hungry soils. *Ferrugineous loam*, or till, is of a dark brown, or reddish colour, much harder and heavier than the other loams. It consists of elay and the calces of iron more or less intimately mixed.

BOGGY SOIL consists chiefly of ligneous particles, being the roots of decayed vegetables mixed



with argillaceous earth and sand, and a coaly substance derived from decayed vegetables.

HEATHY SOIL is that which is naturally productive of heath.

Of the various soils, which we have now described, some are much better adapted to support vegetation than others. Some are too stiff and retentive of water, others too loose and too little retentive. Whatever will meliorate the soil in these particulars, is called a manure; and different soils, of course, require different manures. Those substances, too, that improve the soil by supplying coaly matter, and certain salts, as dung and composts of every kind, are termed manures; but as all soils require this kind of manure, when exhausted of those principles, I shall confine my observations to manures of the first class, which act chiefly in a mechanical way.

I may however first observe, that paring and burning the land improves the soil; by reducing to ashes the old roots, and thus affording the same nutriment to fresh vegetables; as is supplied by dung or other compost. Burnt gypsum and quick lime answer the same end, by aiding the putrefaction of the old grass, and dead vegetables.

Our first object must be to ascertain in what particular any soil is deficient, and the next to discover a manure that abounds in the particular earth required.

To ascertain precisely the composition of a soil, requires a great deal of chymical knowledge; but for common purposes a sufficient degree of accuracy will be obtained, by attending to the discriminating qualities of the different soils, that I have given in describing them. The chief substances employed as manures are chalk, lime, clay, sand, marl, and gypsum; all of which I have described in a former essay. The particular earth in which each abounds, as well as the properties by which they are distinguished, may be learned by attending to that description.

The situation of the land will make some difference in the proportions of the different earths requisite to form a fertile soil. On a declivity, for instance, the soil requires more clay than on a plain. In a very rainy country, again, a lighter and more sandy soil is necessary, than where there is less rain. In the rainy climate of Turin, the most fertile soil has from seventy-seven to eighty per cent of siliceous earth, and from nine to fourteen of calcareous; whereas in the neighbourhood of Paris, where there is much less rain, the *flex* bears only the proportion of from forty-six to fifty-one per cent in the most fertile parts.

The following observations will serve as general rules for the adaptation of manures to the soils.

*Clayey soils* require calcareous earth for a manure, and in that form that is best fitted for opening the

texture of the soil, and making it less retentive of moisture. For this purpose nothing answers so well as marles; and of these a gravelly marl, or as it is called by some limestone gravel, which is a marl mixed with lumps of limestone, is the best. Calcareous marl is next in goodness; next the siliceous; and, lastly, the argillaceous. Where these manures cannot be had, a mixture of coarse sand with lime or chalk; and, if these are not to be procured, coal-ashes, chips of wood, burnt clay, coarse brick-dust, gravel, or even pebbles, will prove useful.

*Clayey loams* may be defective either in the calcareous ingredient or the sandy, or in both. If in the first, the proper manure is chalk; if in the second, sand; and if in both, siliceous marl, limestone gravel, or mild lime and sand.

There is a limestone, found in Yorkshire and some other counties, called by the farmers hot lime, which, if used in the same quantities with common lime, is very injurious to vegetation. It has been lately examined, and found to contain a large proportion of magnesia. This magnesian limestone is easily distinguished from that which is purely calcareous, by being much more slowly dissolved in acids, even the softest kind being much longer in dissolving than marble.

*A chalky soil* wants both clay and sand, or gravel, therefore the best manure for it is a clayey or sandy loam; but when the chalk is so hard, and so

difficultly reducible to powder, as to keep the soil sufficiently open of itself, then clay is the best manure.

*Chalky loams*, or light limestone soils, which do not differ from them essentially, require clay or argillaceous marl.

The best manure for *sandy soils* is calcareous marl; the next best is argillaceous marl; and next to these clay mixed with lime, or calcareous or argillaceous loams. Lime or chalk are less proper, as they do not give sufficient coherence to the soil; but, when mixed with earth or dung, they answer very well.

*Sandy loams* are most benefited by calcareous or argillaceous marls, or by chalk for a first, and clay for a second dressing.

*Boggy soils*, after draining, generally require burning; and, as they are mostly clayey, they should have limestone gravel, or lime mixed with coarse sand; but if, as sometimes happens, they are sandy, lime or calcareous marl may be required.

The above are to be considered only as general rules; and as the soils partake more or less of the nature of those described, the manures must be selected that correspond more or less with those recommended.

## ESSAY XIX.

### THE METALS.

ALL the metals are simple substances. According to the latest discoveries, there are twenty-one distinct metals. Their names are as follows: 1. platina; 2. gold; 3. silver; 4. quicksilver; 5. copper; 6. iron; 7. lead; 8. tin; 9. zinc; 10. antimony; 11. bismuth; 12. cobalt; 13. nickel; 14. manganese; 15. uranite; 16. sylvanite; 17. titanite; 18. chrome; 19. arsenic; 20. molybdenite; 21. tungstenite.

Metals are distinguished from other substances by their great specific gravity, by their brilliancy, and by being more or less ductile or malleable. In this latter property, however, they differ considerably; and those which possess it in the greatest degree are termed metals, whilst the others are called semimetals. Platina, gold, and silver, undergoing no oxydation or calcination in our furnaces, are called perfect or noble metals, and the others imperfect or base.

Previously to noticing such interesting circumstances respecting particular metals, as I have selected for this essay, I shall make some few observa-



tions upon the ores of metals in general, as they are discovered in the mines.

Metals are found in four different conditions.

1st. They are sometimes found in their metallic state, either pure and alone, or alloyed with other metals; in which state they are called native. Gold is generally found in this condition; silver, mercury, copper, and cobalt, not unfrequently; and now and then iron, tin, and lead. In this state they only require pounding, washing, and then fusing or melting.

2dly. They are found mixed with sulphur, and sometimes arsenic, when they are said to be mineralized. In this state they are brittle, and have not always the metallic lustre. These ores are usually called pyrites, of which the iron pyrites are by far the most common.

Metals thus mineralized, after being broken down or pounded, are separated from the mineralizer by torrefaction, or roasting; the heat driving off the sulphur or arsenic.

3dly. Metals are found in a state of calx or oxyde, that is, combined with pure air or oxygen, and mostly with a proportion of carbonic acid. These ores are friable, have an earthy appearance, have different colours according to the degree of oxydation, and have no lustre.

They are reducible to the metallic state by heat alone, or with the addition of charcoal. Iron, cop-

per, tin, lead, and some others, are occasionally met with in this state.

4thly. They are found combined with some of the acids, in which case they are often regularly crystallized. When combined with the vitriolic or sulphuric acid, they are termed vitriols; as green vitriol or vitriol of iron (sulphate of iron); blue vitriol or vitriol of copper (sulphate of copper;) and white vitriol or vitriol of zinc (sulphate of zinc).

In one or other of these states now described are the metals found, principally in the crevices of rocks, and they are called ores. Sometimes they are found in sands and the beds of rivers, as gold in its native state; and frequently the metallic salts are found in natural waters, which are then called mineral waters.

The ores, filling up the crevices in rocks and mountains, are termed veins. These veins sometimes contain nothing but the ore, but more frequently it is mixed in a confused manner with some earthy or stony substance, generally of the siliceous class, and this is called the matrix.

The ore is extracted with iron crows, or other implements; and recourse is frequently had to gunpowder, to separate pieces of the rock, and make way for the working of the veins of ore.

The working of mines is now become quite an art. The mode of doing it depends upon the

situation and direction of the vein, the nature of the rock or mountain in which the vein runs, and several other circumstances, that none can appreciate but those that are in the habits of attending to such business.

There are few circumstances that indicate the presence of a mine, and none that can be absolutely depended upon. This, however, may be remembered, that granite rocks very seldom afford any, but that veins generally run in the secondary mountains, as those of schistus, and such calcareous stone as retains no impression of animals or vegetables. The presence of a stone called heavy spar, too, is reckoned a favourable sign; but the operation of boring can alone decide, whether our suspicions respecting the presence of a mine are well or ill founded.

GOLD is found in its native state in the sands of many rivers, and particularly in those of South America. It is obtained by washing such sand, and picking out the grains of gold; or by powdering the earth or sand, and then adding quicksilver. The quicksilver will unite with other metals, but not with earths; it is therefore intimately mixed with the earth or sand, that contains gold or silver, and uniting itself to those metals affords an easy means of separating them from all impurities. The quicksilver is afterwards driven off by exposing the mixture to a strong heat.

Surprising as it may appear, yet it is true, that gold exists in a variety of vegetables, and may be obtained by a careful analysis of their ashes, and likewise by that of vegetable mould. The quantity however is too minute to make it a profitable employment. This metal is so very malleable, that one grain weight of it may be beaten out into gold leaf, sufficient to cover fifty-six square inches. What is used for the coin of this kingdom is not pure, but alloyed with a certain proportion of copper.

In the art of gilding upon copper, silver, brass, &c., the gold is applied in a variety of ways, some of which we shall describe. 1st. *Hot gilding*. In this the metal to be gilt is immersed in, or washed with a solution of quicksilver in aqua fortis. This gives it a mercurial surface, to which is afterwards to be applied an amalgam of gold, that is, a mixture of quicksilver and gold. The article being now exposed to heat, the mercury flies off, leaving only a thin covering of gold.

If iron is the metal to be gilded, it must be first immersed in a solution of blue vitriol (sulphate of copper) to acquire a surface of copper, which will receive the gilding, whereas iron itself will not.

The colour of this kind of gilding is heightened by burning on it a covering of what is called gilder's wax, which is formed of wax, verdigrise, and blue vitriol. It is lastly polished, and brightened with

a boiling solution of common salt and cream of tartar.

The second mode is called the *Grecian gilding* of silver. A salt, called sal alembroth, which is a triple salt containing marine acid, ammonia, and mercury, is added to a solution of gold in aqua regia, which is a mixture of marine acid and aqua fortis, called aqua regia, from its property of dissolving gold, which neither of them possesses separately. This is evaporated to the consistence of oil, and applied to the silver that is to be gilded.

The third kind, called *cold gilding*, is performed by rubbing the metal with the ashes of linen rags that have been impregnated with a solution of gold in aqua regia. Gold wire is made by coating a silver rod with gold-leaf, and afterwards drawing it out into wire, which may be drawn so fine that the covering of gold in some places does not exceed the fourteen millionth part of an inch.

SILVER is alloyed with copper, both for coinage, and for silversmiths' work, which renders it much more hard and durable. In the coinage of this country nearly one twelfth of copper is allowed. Any other metal may be silvered by rubbing it with a paste made in the following way. Dissolve fine silver in aqua fortis, and then add as much tartar finely powdered as will make it into a paste. The modes employed for giving a surface of silver to other metals are very numerous. The plating of



copper is performed by fastening plates of silver upon thicker plates of copper, and then rolling the two together into thin plates. The copper is generally twelve times thicker than the silver, and one ounce of silver is often thus rolled out to a surface of three square feet.

What is called French plate is made by covering the copper, or more commonly brass, with silver leaf when heated.

MERCURY, or quicksilver, which differs from all other metals in being fluid at the temperature of this climate, has however been frozen both by the natural cold of high northern latitudes, as at Kamtschatka, and by artificial cold, produced by mixtures of snow and aqua fortis. It is found to congeal at forty degrees below zero of Fahrenheit's scale. Mercury unites with other metals, forming always a soft mass, termed an amalgam. On this property depends the art of gilding, as above described, and also the art of coating looking-glasses.

To silver looking-glasses in the usual way, a sheet or leaf of tin foil, of the size of the glass, is spread out upon a table; mercury is then poured upon it, and rubbed about with a brush; and more mercury poured on, till it covers the tin a full line in thickness. The glass is now to be slid upon it, pressing its edge close down, and along the tin. The glass must then be very equally pressed with weights, and allowed to remain so for two or three days.

For convex and concave mirrors, which cannot be so pressed, an amalgam is used that is formed of two parts of mercury, one of tin, one of lead, and one of bisinuth.

Mercury, when combined with sulphur, is called cinnabar, whether it is a natural or artificial combination; and the best cinnabar, when finely levigated, forms the beautiful paint called vermilion.

It is usually in the form of cinnabar, that mercury is found in the mines; but sometimes it is found pure in beds of calcareous earth or of clay. There are but few mines of quicksilver; the greatest quantity is procured from Spain. To separate the mercury from the sulphur, quicklime or iron filings are added to the cinnabar to detain the sulphur, whilst the heat drives off the mercury.

COPPER is used in a variety of the arts. With tin it forms bell-metal and gun-metal, and with a metal called zinc it forms brass; or, if a less proportion of zinc is employed, an ornamental and useful compound, called Pinchbeck.

Vessels made of copper for culinary purposes are highly prejudicial; for all acids, and all oily or fatty substances, when allowed to turn rancid, combine with the copper, and form verdigrise, which is poisonous, if taken in sufficient quantity, and very detrimental, even in the smallest quantities. Copper boilers must consequently be highly improper; for it is impossible to keep them so clean,

but that some verdigrise will be formed about the edges, and unevennesses, where the oily or fatty matters are sure to lodge.

To prevent these bad effects, most copper vessels are tinned on their insides. To do this, the surface is well cleaned, by rubbing it either with sal ammoniac, or an acid; the tin, or a composition of tin and lead, or lead and pewter, is then melted in the vessel, and rubbed well about with old rags doubled up. But this tinning, let it be remembered, does not wholly prevent the bad effects of the copper, as it soon wears off.

It has been usual to attribute the unpleasant effects, often experienced from tea, to its being somewhat impregnated with copper, from being dried on plates of that metal; but it is now known, that iron plates, not copper ones, are employed for that purpose. The ill effects of tea must therefore be attributed to its own properties, or perhaps in a great measure to the debilitating power of hot water.

Verdigrise for sale is made by putting sheets of copper in alternate layers with a mixture of four wine and the refuse of grapes. After a certain time the plates are taken out, and placed edgewise in a cellar, where they are repeatedly sprinkled with four wine. The verdigrise, as it is formed on the surface of the copper, is scraped off, and packed up in leathern bags for the market.

Blue vitriol, we have before said, is a sulphate of copper. The common mode of browning fowling-pieces is to wash the barrels with a solution of this in water, by which a layer of copper is deposited, and this is less affected by the weather than iron. The sulphate of copper is used in dyeing, crystals of verdigrise in painting, and copper itself in a variety of ways.

IRON is chiefly found in the form of an oxyde, that is, combined with oxygen. It is diffused more through different natural productions than any other of the metals. It exists in small proportion in most animal and vegetable, as well as in most mineral productions. According to the degree of oxydation, it assumes different colours. It is the colouring substance of most of the gems and precious stones, of the different clays, and other earths, and of a variety of paints and pigments.

From the variety of conditions, which it is capable of assuming, according as it is mixed with more or less carbon, and oxygen, it is the most useful of metals,

It is the proportion and state of combination of these substances with iron, that constitutes the difference between iron and steel, between cast iron and forged iron, between red short iron and cold short iron, and between all these and plumbago or black lead. When combined with a certain proportion of carbon or charcoal it constitutes steel,

and with a much larger proportion it forms plumbago; for which last, therefore, black lead, as it is generally called, is a very improper name. The uses of iron in these various states it is needless to mention.

The plumbago is found most abundantly in Cumberland. It is sawed into small slips, to form the black lead pencils; but an inferior sort is made by mixing up the black lead dust into a paste.

Iron combined with vitriolic acid forms green vitriol; from which, when dissolved in water, the iron is precipitated in form of a black powder, by adding to it any vegetable astringent, as galls, oak bark, or the like. On this depends the art of making inks, and black dyes. A very good ink is made by the following proportion of ingredients.

Nut-galls, one pound;

Gum arabic,        }  
Green copperas, } of each six ounces;

Water four pints.

The galls are to be bruised and suffered to stand in the water (being now and then shaken) for four hours. The gum is next to be added, and when this is dissolved, the copperas. The liquor immediately becomes black, in consequence of the precipitation of the iron; and the use of the gum is to suspend the black powder, which would otherwise fall to the bottom. Inkstains may be easily taken out by any of the acids, either from cloth, paper, or



wood. Lemon juice is the best, because with it there is no danger of injuring the article. The acids will only take out writing ink, not printing ink, and therefore they may be used for cleaning books that have been defaced by writing.

When ink-spots have remained long, they become iron moulds, and are then taken out with more difficulty; and the more so, the longer they stand, in consequence of the iron, by repeated moistening and exposure to the air, having acquired such an addition of oxygen, as to make it insoluble in acids. To discharge these old stains, an alkaline sulphuret, or liver of sulphur, should be first applied in solution, and after this is well washed off, the lemon juice or other acid should be applied.

As connected with this, I shall here mention the best mode of taking out fruit or wine stains, and spots of grease or of wax. For the first, put about a table spoonful of marine acid (spirit of salt) into a teacup, and add to it a tea spoonful of powdered manganese. Then set this cup in a larger one filled with hot water. Moisten the stained spot with water, and expose it to the fumes, that arise from the teacup, till the stain disappears.

The fumes are those of the oxygenated muriatic acid; but as they discharge all printed and dyed colours, this mode is only applicable to white articles.

Grease-spots are most effectually removed by a diluted solution of pure potash, or caustic lie. Stains of white wax are taken out by spirit of turpentine, or sulphuric ether; and the marks of white paint may likewise be removed by the last mentioned substance.

Prussian blue, so much admired as a pigment, is a combination of iron with a peculiar acid, called the Prussic acid. It is obtained, by a complicated process, from blood and some other animal productions.

I shall conclude these few observations respecting iron, with the process of making what are called tin plates; for you must know that these plates are not tin, but iron slightly coated with tin. What are usually called tin vessels, therefore, are iron vessels, having the surface covered with tin; and such only as are said to be made of block tin, are really composed of that metal.

Soft iron is made into plates, by rolling, for this purpose; and they are cleansed by immersion in water acidulated by the fermentation of malt, which is called four wort. When dried the plates are dipped into a bath of melted tin, the surface of which is covered with pitch or tallow; they are turned in this bath, and then taken out; after which they are scoured with sawdust or bran.

LEAD is often found mineralized by sulphur, in pieces of a cubical form, denominated *galena*. It

is often mixed with small quantities of arsenic or of silver, the latter being in the largest quantity in those cubes or dice that are smallest in size.

Lead oxydated or calcined in different degrees assumes different colours ; first gray, as the dull crust, that always covers lead that is exposed to the air ; secondly, yellow, as the oxyde of lead, called masticot ; thirdly, red, as minium or red lead ; fourthly, a reddish yellow or orange, as the scaly oxyde, called litharge ; and, lastly, white, as the white lead, used by painters, which is obtained by exposing sheets of lead to vinegar in an uniform heat, as that of a hotbed, or by exposing it to the vapour or steam of vinegar.

To make shot, a small quantity of arsenic is melted with the lead, to render it more brittle ; and when it is so far cooled, that a card may be plunged into it without being burnt, it is poured into a kind of cullender, pierced at the bottom with many holes, and containing lighted charcoal. This cullender is held over water, and the lead assumes a round form as it passes into it.

Lead has very injurious effects upon the constitution, when taken in any way along with our food, or when introduced into the body by other means, as by exposure to the dust or fumes of lead, or by suffering white lead in the form of paint to remain on any part of the surface of the body. It is a frequent cause of disease amongst plumbers and pain-

ters; and several instances have occurred of ladies using white paint having brought on very alarming symptoms thereby, and sometimes even death.

Water kept in leaden vessels for a length of time becomes impregnated with it: and sometimes even pump water, in consequence of this metal being used in the construction of the pump, and pipes, has been so much impregnated with it, as to effect the health of those who drank it. To avoid the possibility of this, the water that is lodged in the pump and pipe should be first pumped off, before the water is taken for use.

Sugar of lead, which is lead dissolved in vinegar and crystallized, is sometimes fraudulently added to bad wines to clarify them, and often to take off a slight acidity. It is likewise added to brandy, to deprive it of colour.

To detect lead in water, the most delicate test is water impregnated with sulphurated hydrogen gas (as the Harrogate water). To the suspected water add half its bulk of this sulphureous water, and if lead is present it will give a dark brown or blackish tinge.

To detect lead in wines, add a few drops of the following liquor to a glass of the wine, and the lead if present will be precipitated of a black colour. Take of calcined oyster-shells and crude sulphur equal parts; keep them in a white heat for fifteen minutes; when cold, add an equal quantity of

cream of tartar, and boil it in water for an hour in a glass vessel. When the powder has subsided, decant the clear liquor into phials, holding an ounce each, and add twenty drops of muriatic acid (spirit of salt) to each phial. Let the phials be kept well corked. Copper, if present, will be precipitated by this liquor as well as lead.

TIN is a metal that is procured in very great abundance from the mines in Cornwall, chiefly in form of a white ore, with quartz for its matrix. Mixed with lead and antimony, it forms pewter, a compound that is used for a variety of purposes. Tin alone is often made into kitchen utensils; but it is more frequently employed as a coating for other metals that are more lasting, as iron or copper.

Pins are made of brass wire, and are afterwards tinned by the following process. A proper vessel is filled with alternate layers of pins and plates of tin, the latter being both at top and bottom. A solution of cream of tartar in water is then poured upon them, so as to fill the vessel, and is made to boil for four or five hours, when the pins are taken out completely tinned.

The acid of the tartar in this process dissolves the tin first, and then gradually deposits it on the surface of the pins, in consequence of its greater affinity for the zinc, which enters into the composition of the brass wire, of which the pins are formed.



Tin is very easily calcined, as is seen by the surface of melted tin or pewter being very soon covered with a powdery calx, which the purchasers of old pewter call dross, and pretend to make no use of, and therefore pay only for the remainder. They however well know that this dross, as they call it, which is a true oxyde of the metal, when exposed to a strong heat with charcoal, is easily reduced to the metallic state, and forms good pewter. The same deceit is often practised by plumbers, when they purchase old lead.

The calx or oxyde of tin is called putty; and is used in polishing hard bodies, and to convert glass into a kind of enamel.

A solution of tin in muriatic or in nitro-muriatic acid is used by dyers, as a fixer of colours, and particularly in dying scarlet.

Three parts of tin, with five of bismuth and two of lead, form a compound so easily melted, that it liquifies in boiling water.

The specula for reflecting telescopes are a compound of tin, copper, and arsenic.

ZINC is a metal that enters into the composition of brass and bell-metal. It is found abundantly in Somersetshire, Derbyshire, and Flintshire, in an earthy form, of a gray colour, without lustre, called calamine. This is an oxyde or calx of zinc, usually combined with fixed air. It is found in North Wales, in Cornwall, and in Derbyshire, in an ore

called blend, or black jack, greatly resembling galena, which is an ore of lead. In this state the zinc is mineralized by sulphur. These ores are both used in making brass. Calamine is, however, preferred. After being calcined and powdered, it is mixed with charcoal and copper, in thin plates, or in grains, and exposed to a heat, at first not sufficient to melt the copper, but afterwards increased; so that the mass, which is a compound of the two metals, is fused, and is now called brass.

Zinc is the metal that is generally selected for exhibiting the phenomena which have received the denomination of Galvanism; and I shall, therefore, in this place, take notice of that newly discovered property which is found to belong more or less to all the different metals.

**GALVANISM:** more than thirty years ago it was discovered, that when two pieces of metal, the one of lead, the other of silver, are joined together, so that their edges form one surface, a certain sensation will be produced on applying it to the tongue, which comes near to the taste of martial vitriol or copperas; whereas each piece by itself betrays not the least traces of that taste.

No further notice seems to have been taken of this fact, and no other Galvanic phenomenon discovered, till M. Galvani, an Italian, was led to a variety of experiments on the subject, which he published ten or eleven years ago, and from whom

the term Galvanism is derived. Since this time the attention of the learned has been a good deal directed to the subject, and many very curious circumstances have been ascertained, particularly by the very late discovery of what is termed the Galvanic pile, by S. Volta.

We shall not enter into the minutiae of Galvanism, either as to the history of its discovery, or the phænomena it comprises. With respect to the first I shall add nothing to what has been said above; and with regard to the phænomena, the following are the most remarkable.

When one piece of metal is laid on the tongue, and another of a different metal is held between the upper lip and the gums, a taste of copperas, and frequently a flash of light is perceived, the moment that the two metals are brought into contact.

The nerve of a living animal, or of an animal newly slain, being made part of the circle of communication, the muscles to which that nerve runs, are convulsed at the moment the communication is made. Thus, the lower extremities of a frog being separated from the body, and the sciatic nerves laid bare being placed on a plate of zinc, and the toes of the frog upon a plate of silver, as soon as a communication is made between the two plates by any metallic wire, the legs of the frog become convulsed.

When alternate layers of silver, zinc, and moistened cloth, or pasteboard, are piled upon each other successively, to a considerable number, all the Galvanic phænomena are rendered more evident on forming a communication between the top and bottom of the pile, which must have different metals at those two places.

This is called the Galvanic pile, the chief properties of which are the following; and, to make them the more evident, let there be as many as fifty pieces of each metal; let the silver be half-crowns, and the zinc of the same size, but rather thicker; and, lastly, let the circular pieces of cloth be wetted with salt and water.

On applying one hand, wetted with salt and water, to the top, and the other to the bottom of the pile, a shock, similar to that from a charged electric jar, is immediately felt in both arms.

When a wire from the top, and another from the bottom, are placed, one upon, and the other under the tongue, a pricking sensation, and somewhat of an acid taste, is perceived.

When the head is made part of the circuit, the wires being placed in the ears, a crackling sound is heard; and a flash of light appears if the eyes are brought into its course.

If, by means of the wires, the Galvanic fluid is directed over a sore, or any part where the skin

is abraded, a smarting and considerable pain is induced.

When water is made part of the circle of communication, by introducing the wires under water, and bringing them near to, but not into contact with each other, a slow but continued decomposition of the water is the consequence. If the wires are of iron, or any metal that is oxydable, only hydrogen gas escapes in bubbles to the surface, the oxygen uniting with, and oxydating the wire. But if gold wire be employed, both oxygenous and hydrogenous gasses are disengaged.

By means of this simple apparatus, which possesses the above properties as long as the pieces of cloth remain moist, a variety of interesting chymical experiments have been performed. It exhibits nearly the same effects, as a chymical agent, with those produced by repeated shocks or sparks from an electrical machine.

♦ **COBALT** is a metal that is chiefly obtained from the mines in Saxony. When deprived of arsenic, with which it is generally mineralized, it is called zaffre. This mixed with three parts of sand, and one of potash, is melted into a blue glass, which, being powdered and washed, is known by the name of smalt, or azure; and this, by mixture with starch, forms the blue used by laundresses, and is made the basis of many blue paints.



ARSENIC is the last of the metals which we shall mention ; and this, chiefly, with a view of noticing its baneful effects as a poison. Miners, and other workmen, who are exposed to the dust and fumes of this mineral, and particularly those of the cobalt mines, are so soon, and so violently affected by it, that they live but a few years in the employment, and are subject to pulmonary affections, and diseases of the abdominal viscera. In Saxony the work is only done by convicts; whose punishment would otherwise have been death.

When taken into the stomach in considerable quantities by mistake, or with an intent to commit suicide, it first sets the teeth on edge, constricts the throat, heats the mouth, and causes spitting. Then comes on a burning heat, and excruciating pain in the stomach, a vomiting of glairy bloody matter, cold sweats, convulsions, and death.

Mucilaginous drinks, milk, oils, and butter, have been the usual remedies recommended in cases, where this poison has been taken; but what is much better than either of these is, a drachm of sulphure of potash (liver of sulphur), dissolved in a pint of water, to be taken at several draughts.

Whilst this is preparing, let the patient take plentifully of vinegar; and if the sulphure cannot be procured, let an emetic be given after the

vinegar; but not at all if the sulphure can be speedily administered.

When it is required to know whether a person has died in consequence of taking arsenic, or whether a dog or other animal may have been poisoned by it, let the contents of the stomach be well washed, and if there is any powder sinks to the bottom, carefully collect and dry it. Let a portion of this powder, mixed with a little charcoal, or other inflammable matter, be thrown upon a red-hot poker; and if it is arsenic it will fly off in vapour, giving, in a strong degree, the odour of garlic.

With this short account of the most important of the metals I conclude the consideration of the chymical elements. I have not attempted to give a complete history of each elementary substance, and of all the compounds that result from them, for it was not my intention to offer a system of chymistry. I have only selected such as were either curious or important, and such as would naturally lead to subjects that were interesting and useful. In my selection, I trust, that I have not altogether failed either in amusing or instructing; and should any one, by the perusal, have imbibed a relish for that science, which I have here endeavoured to place in a pleasing point of view, though not more so than it deserves, my intention is completely answered.

I shall now add an essay or two on the mineral waters, which come properly to be treated of after the metals, and other mineral productions; and shall then conclude the work with the consideration of some few of the arts that are intimately connected with chymistry; but for introducing which, no convenient opportunity occurred in the consideration of the chymical elements.

## ESSAY XX.

## MINERAL WATERS.

THE term of mineral water has, by common consent, been given to all natural waters, which have been found useful in the treatment of disease; and it has generally been restricted to such waters, although there are many others, that contain larger quantities of different mineral productions.

Some, as the Malvern waters in Wales, are chiefly useful in consequence of their containing less heterogeneous matter than even common spring water, and yet these are denominated mineral waters; whilst various others, containing the sulphate of copper, large quantities of common salt, or other mineral productions, are seldom enumerated among the mineral waters, because not applied to medicinal purposes.

It is very difficult to free any kind of water from all foreign admixture; even rain, or snow water contains a portion of calcareous earth, besides a quantity of common atmospheric air; nor is it wholly deprived of the former by repeated distillations. What we denominate hard waters contain selenite (a sulphate of lime) and generally chalk.

Many springs too, which afford good wholesome water, that is used for all domestic purposes, are impregnated with small quantities of different kinds of salts, with iron, or with fixed air.

It is only those waters, that by their containing greater abundance of these impregnations, or from some other cause, have obtained considerable celebrity in the treatment of diseases, that I shall now notice; and these I shall class, and describe in order, according to their predominant qualities.

## CLASS I. SIMPLE WATERS.

### DIVISION 1<sup>st</sup>. *Cold.*

Several springs have acquired celebrity, which are remarkable for their purity, containing much less of earthy or saline impregnations than the spring waters in common use. They are chiefly employed as an external application in scrofulous or other old ulcers, in different chronic eruptions, and in sore eyes. Internally they are recommended in calculous complaints, and other affections of the kidneys or bladder.

The most noted water of this class is that of the *Holy-well* at *Malvern*, in *Worcestershire*, which, except a small quantity of fixed air, contains scarcely any foreign ingredients.

*St. Winifrede's well* at *Holywell* in *Flintshire* is



celebrated for similar virtues, and is likewise a remarkably pure water.

DIVISION 2d. *Thermal, or warm.*

The most celebrated of this division are Bristol, Matlock, and Buxton waters; which are tolerably pure waters, containing no metal or metallic salt, and no great quantity of other foreign matter. Their virtues chiefly depend upon their warmth; and the advantages received by invalides, visiting these fashionable resorts, are in a great measure derived from other adventitious circumstances, as variety of scenery and amusements; the genial warmth of Bristol, or the enchanting scenery of Matlock, never failing to excite to exercise, and to exhilarate the spirits of the hypochondriac or the exhausted debauchee. These waters being amongst the most noted in the kingdom deserve more particular notice, and shall be therefore treated of separately.

*Bristol hotwell.* This is a pure warm slightly acidulated spring. It contains less solid matter than most common springs, but is considerably impregnated with fixed air. Its temperature upon an average may be reckoned at 74°.

The site of Bristol hotwell is peculiarly favourable to invalides; being sheltered from the north, east, and west winds, and only open to the south. It is chiefly on this account, that it has obtained so much celebrity for consumptive patients.

The internal use of the waters is likewise serviceable in the hectic stage of that complaint. - It is particularly recommended to patients labouring under the effects of a long residence in a warm climate, to dyspeptics, and to persons subject to bilious diarrhœa and to dysentery. Its use is likewise extended to calculous complaints, and to diabetes.

From its excellent property of keeping untainted for a long time in hot climates, it is frequently exported, though its medical virtues are considerably less, if not taken at the spring. The water of the Sion spring at Clifton only differs from the last in being one or two degrees colder.

*Matlock* in Derbyshire. There are several springs here uniformly warm, being at 66°. The water is a pure spring water without any impregnation of fixed air.

It may be drunk in all cases, where a pure di-  
luent is adviseable; but its notoriety chiefly depends upon its use as a bath. Though warm, it is considerably below the temperature of the body, which is commonly 97° or 98°. Immersion in the Matlock bath is therefore attended with some shock, though considerably less than common cold or sea bathing.

It is chiefly recommended in chronic rheumatism, and all such cases as require ultimately the cold bath; but where from the delicacy of the pa-

tient's habit, it is necessary to bring him gradually to its use. It forms a proper intermediate bath between Bath or Buxton and the sea.

*Buxton* in the Peak of Derbyshire. This water is, like the last, as pure as common spring water, except that it contains a small quantity of azotic gas; and a larger quantity continually escapes in bubbles to the surface of the water in the springs. This gives to it no particular flavour or appearance, and, as far as is yet known, no particular medical virtues. Its temperature is at  $82^{\circ}$ , being considerably warmer than that of Matlock, though not so warm as the human body. Its chief use as a bath is in cases of partial loss of motion or of sensation, particularly after rheumatism. As an internal remedy it is serviceable in cases of indigestion from free living, and in diseases of the urinary organs. Its utility in gouty affections is more doubtful.

## CLASS II. CHALYBEATE.

### DIVISION 1st. *Hot carbonated.*

*Bath* water, though slightly chalybeate, contains so small a proportion of foreign ingredients, that it falls properly to be considered after the simple thermal waters.

The climate of Bath is mild and genial. Its waters have three principal sources, which supply the King's bath, the Cross bath, and the Hot

bath, which differ somewhat in their temperature, as well as contents.

The first is at  $116^{\circ}$  when fresh drawn, and about  $106^{\circ}$  in the bath; whilst that of the Cross bath, which is coldest, is only  $112^{\circ}$  at the pump, and from  $92^{\circ}$  to  $94^{\circ}$  in the bath.

The former is likewise more chalybeate; although even that is so slightly so, as only to be evident to the taste when warm, and not at all when cold. Besides this small quantity of iron, Bath water contains some fixed air, though not so much as to render it sparkling, or at all acid to the taste. Its other ingredients are calcareous salts enough to render the water hard, a minute portion of neutral salts, and of siliceous earth, and a small quantity of azotic gas.

Used internally, Bath water sometimes produces headach, dryness of the tongue, and a feverish pulse; when this is the case, its further use should not be advised. When likely to prove beneficial, it produces an agreeable glow in the stomach, and an increase in the appetite, and spirits; it also quickly determines to the kidneys.

Bath water, both internally and externally applied, is very beneficial in chlorosis, in irregular gout, and the secondary stage of rheumatism. In paralytic affections, where there is no particular determination to the head; in jaundice, and other liver complaints, brought on by residence in hot climates; and in most

hypochondriacal and dyspeptic cases, the use of the Bath waters is highly extolled.

In cases of old sprains, or the partial effects of rheumatism, the topical application of the water, by pumping it upon the part, is frequently serviceable.

We have no other hot chalybeate waters in this country; but on the continent several have gained great celebrity, as *Vichy waters* in the Bourbonnois, a mountainous district in the centre of France; which waters, besides being chalybeate, are alkaline, containing a very perceptible quantity of mild soda. Their temperature is about 120°.

*Carlsbad*, or *Caroline waters*, in Bohemia, are hot saline carbonated chalybeates. Their temperature is as high as 165°. They contain Glauber's salts, and other purging salts, much fixed air, and calcareous earth, and a small portion of iron. The two last being held in solution by the redundant fixed air, are separated (the former in considerable quantity), when the water by exposure loses its heat and its fixed air; in consequence of which stalactites and calcareous petrefactions are very common in these springs.

These waters are purgative as well as tonic, and are useful in the same cases as the Bath waters.



DIVISION 2d. *Cold carbonated.*

This division of mineral waters is the most abundant, not only in this, but in other countries.

Besides fixed air and iron, many of them contain no foreign ingredients but such as are found in the most common springs. The quantity of these two ingredients, to which they owe all their virtues, varies considerably in different waters.

Such as contains but a small quantity of the gas, not sufficient to give it a sparkling appearance, is termed simple carbonated chalybeate water; and of this kind are all the natural simple chalybeate springs in this country, as *Tunbridge*, *Ipsington*, &c.

Those chalybeate waters, that sparkle, and are sensibly acid from the abundance of the gas, are called highly carbonated chalybeate waters. Of this class are the *Spa waters* in the principality of Liege, and the *Pyrmont water* in Westphalia, which are frequently imported into this country, and are the mineral waters that we most frequently imitate by artificial means.

Amongst the simple chalybeate waters of this kingdom, *Tunbridge-wells* is most resorted to; but those at *Ipsington*, *Hampstead*, *Carlton* near Newark, *Lecz*, *Markshall*, and *Felstead* in Essex, *Aylesham* in Norfolk, and *Wellingborough* in Northamptonshire, are of the same class, and many of them as strongly impregnated.

There is a cold chalybeate at *Buxton*, and like-

wife at Harrowgate, that add to the celebrity of these places.

Waters are known to be chalybeate by their striking a purple or black colour with an infusion of galls, or other vegetable astringent; by their peculiar inky flavour; and by their depositing a yellowish ochre, when exposed to the air.

Their medical virtues are chiefly as a tonic, producing a genial glow, improving the digestion, and giving strength and tone to the whole system. They are particularly serviceable in chlorosis, and other diseases of females; in flatulency and indigestion, and in all cases of debility from free living or debauchery.

The highly carbonated class, as Spa and Pyrmont, have a kind of intoxicating effect from the excess of fixed air, and frequently require to be diluted; and are never to be drunk, where there is much inflammatory action, or determination of blood to the head.

It is by means of the fixed air that these waters retain the iron in solution; if, therefore, they lose this gas, which they gradually do, by mere exposure, and more quickly by boiling, the iron is precipitated in the form of ochre, and the water loses all its virtues and peculiar properties. If well corked, they may be kept good for some time.

The proper quantity to be taken is from a pint and a half to three pints daily; and the use of the

waters should not be continued more than from six to eight weeks, without a considerable intermission.

Besides the simple and highly carbonated chalybeate waters, there are others that are chalybeate with the addition of saline substances, as the *Cheltenham* and *Scarborough* waters. These are purgative, particularly the former, and are chiefly beneficial in obstructions of the liver, in all glandular swellings, and in cases of scorbutic eruptions.

These waters grow turbid and lose their virtues by keeping, even in bottles well corked. At *Burlington* in Yorkshire, at *Nevil Holt* in Leicestershire, and at *Coventry*, are springs very much resembling in all their properties those of Scarborough: whilst those of *Gainsborough* in Lincolnshire, and *Hartlepool* in Durham, more nearly resemble the Cheltenham, having a slightly sulphureous taint.

#### DIVISION 3d. *Vitriolated.*

This species of chalybeate water owes its property to the presence of green vitriol, which is iron combined with sulphuric or vitriolic acid. It also contains a portion of alum, and hardly any other foreign matter.

These waters are not numerous; their strength varies, and of course the dose; it ought, however, seldom to exceed a pint in a day. In a large

dose they produce vomiting. They are useful in hemorrhages and other discharges from debility, and in patients of a general lax habit.

At *Shadwell* near London, at *Hartfell* near Moffat, and at *Swansey* in South Wales, are springs thus impregnated.

### CLASS III. SALINE.

#### DIVISION 1st. Simple.

These are waters that differ from common water in holding in solution more or less of the different purging salts; but they contain no iron, and no fixed air, or sulphureous gas. The salts are chiefly either Epsom salt, or Glauber's salt, or both, with muriate of magnesia, and more or less of common salt.

*Sedlitz* and *Epsom* water abound in sulphate of magnesia or Epsom salt.

*Sea water* owes its saline taste to common salt (muriate of soda), which it contains in abundance; and its bitter taste to muriate of magnesia, of which it also contains a considerable portion.

Both these salts are purgative; and the sea-water differs but little, if at all, in its medical virtues from the saline springs, the purgative quality of which is generally derived from Epsom salt, or Glauber's salt.

The Epsom salt for sale is now obtained chiefly

from sea water, by adding green vitriol (sulphate of iron) to the uncrySTALLIZABLE salt that remains after the common salt has been extracted from it. The sulphuric acid of the vitriol leaves the iron to unite with the magnesia of the salt, which is a muriate of magnesia, and thus forms the Epsom salt (sulphate of magnesia.)

The internal use of these salt or sea waters is recommended in glandular, or serofulous swellings; in dyspepsia, attended with nausea, and a foul tongue; in hypochondriasis, attended with costiveness; and in most cases of habitual costiveness, particularly where the more drastic purges have been too freely administered.

*Sea bathing*, or salt water bathing, is useful wherever cold bathing of any kind is indicated; as in all cases of debility, unaccompanied with inflammatory symptoms. How far it is to be considered preferable to the common cold bath is doubtful, except in cases of cutaneous eruptions, and old ulcers, where the stimulating quality of the salt, as an external application, is generally attended with good effects.

In some delicate and irritable habits too, bathing in the sea will be succeeded by that universal glow that is the certain test of the utility of the bath, when common cold bathing would be succeeded by chilliness and coldness of the extremities. Warm



salt bathing may be more advantageous in paralytic cases than common warm bathing.

DIVISION II. *Highly carbonated alkaline.*

The most celebrated natural water of this class is that of *Seltzer*. It is a saline water, slightly alkaline from the soda that it contains, and highly acidulated with carbonic acid or fixed air, which is much more than sufficient to saturate the alkali.

This water is palatable to most persons, being brisk and sparkling, and but slightly alkaline; it raises the spirits, and promotes digestion.

Seltzer is a village in the bishoprick of Triers, in Germany; its water is transported in stone bottles, well corked, to almost every part of Europe. In Holland, as well as Germany, it is a common beverage at the tables of the fashionable; and in this country, either the natural water, or an artificial imitation of it, under the name of *Soda water*, is now a very fashionable drink.

This water is highly recommended in the hectic fevers of consumptive patients, attended with flushings and night sweats; and for allaying feverish irritation from other causes.

In eruptions called scorbutic, in cases of indigestion, and particularly in calculous complaints, its virtues are highly extolled.

The usual dose of the water is, from half a pint

to a pint; but little or no inconvenience can arise from a much larger quantity.

#### CLASS IV. SULPHUREOUS WATERS.

The sulphureous waters of this country are all cold; as *Harrowgate*, in Yorkshire; *Moffat*, in the south of Scotland; *Sutton-bog*, in Oxfordshire; and *Shettlewood*, in Derbyshire.

Those of *Aix-la-Chapelle*, in Flanders, and several others on the Continent, are very hot. The sulphur is retained in those waters by its union with inflammable air, which hepatic gas gives the peculiar smell and taste to them. It resembles that of rotten eggs, or the scourings of a gun-barrel; which, with its property of tarnishing silver, and rendering black, characters written on paper with sugar of lead dissolved in water, are sufficient tests to ascertain its presence in any water.

Some of these waters contain a sensible portion of the purging salts; of which Harrowgate stands the first in renown.

The *Moffat* water contains only a little common salt.

Warm baths of these waters are recommended in almost all cases where their internal use is advised; the principal of which are herpetic eruptions, and such as are termed scorbutic. Dyspeptic patients, and such as labour under worms, experience advantage from these waters. Two or three half-

pint glasses of the water are taken in the course of the morning.

The hot sulphureous waters on the Continent are resorted to by gouty, rheumatic, and paralytic patients; and are used externally as tepid baths, as hot baths; or as vapour baths, with great advantage.

Having thus given a hasty sketch of all the different kinds of mineral waters, I shall add a list or table of the particular springs of this kingdom, with some few of the more noted ones on the Continent. I shall so arrange them, that their peculiar properties may be immediately seen; and shall place the most noted of each kind at the head of its division, as a point of comparison for the rest. I shall, lastly, conclude the subject by an essay on the artificial mineral waters.

TABLE of the Mineral Waters of Great Britain,  
with a few of those on the Continent, system-  
atically arranged\*.

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CLASS I. SIMPLE WATERS.

DIVISION I. <i>Cold.</i>	DIVISION II. <i>Hot.</i>
Malvern, Gloucestershire	Bristol, Somersetshire
St. Winifrede's Well, at	Buxton, Derbyshire
Holywell, Flintshire	Matlock, Ditto
	Mallow, Cork

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CLASS II. CHALYBEATE.

DIVISION I. <i>Cold carbonated simple.</i>	
Tunbridge, Kent	Birmingham Well, near to
Aberbrothick, Scotland	the town
Aylesham, Norfolk	Bromley, Kent
Ballycastle, Antrim	Cannock, near Stafford
Ballyspellan, near Kil-	Carlton, Nottinghamshire
kenny	Chippenham, Wilts

\* Many of the following waters have not yet been accurately analysed. We do not, therefore, presume that all are properly arranged; but judging from their general qualities and characters, we trust that the errors are few, and of little importance. Neither do we offer it as a complete catalogue of British mineral waters, there being, doubtless, many that are not yet generally known.

Cobham, Surrey	Leez, Essex
Colurian, Cornwall	Llandrindon, South Wales
Coolauran, Fermanagh	Markshall, Essex
Derby, near to the town	Millar's Spa, Lancashire
Dortshill, Staffordshire	Moss House, Ditto
Dunnard, near Dublin	Newton Stewart, Ireland
Dunfc, Scotland	Oulton, Norfolk
Felstead, Essex	Peterhead, Aberdeenshire
Galway, Ireland	Sene, Wiltshire
Glanmille, near Naul	Tibshelf, Derbyshire
Glendy, Scotland	Weatherstack, Westmore-
Hampstead, near London	land
Islington, Ditto	Wellingborough, North-
Kanturk, Cork	amptonshire
Kincardine, Scotland	West Ashton, Wiltshire
Kirby, Westmoreland	Wexford, Ireland
Lancaster, or Sale's Spa	Whiteacre, Lancashire
Latham, Lancashire	Wigan, Ditto

DIVISION II. *Hot carbonated simple.*  
Bath, Somersetshire.

DIVISION III. *Cold highly carbonated.*

Pyrmont, Germany	* Ilmington, Warwickshire
Spa, Ditto	Lincomb, near Bath
Abcourt, France	Lis-done-verna, Ireland
Passy, Ditto	Maccroomp, Ditto
	Thetford, Norfolk

\* The waters of this division that are found in this kingdom, have much less fixed air than the Spa waters, which they otherwise resemble.



DIVISION IV. *Cold saline carbonated.*

(a) <i>slightly sulphureous.</i>	(b) <i>not sulphureous.</i>
Cheltenham	Scarborough
Ballynahinch, Down	Astrop, Oxfordshire
Castlemain, Kerry	Afwarby, Lincolnshire
Deddington	Bingley, Warwickshire
Drigwell, Cumberland	Burlington, Yorkshire
Gainsborough, Lincolnsh.	Coventry, Warwickshire
Hartlepool, Durham	Hanbridge, Lancashire
Orston, Nottinghamshire	Jeffop's Well, Surrey
Stenfield, Lincolnshire	Kingscliff, Northamptonsh.
Tarleton, Lancashire	Malton, Yorkshire
Thoroton, Nottinghamsh.	Nevil Holt, Leicestershire
Worksworth, Derbyshire	Newnham, Warwickshire
	Thursk, Yorkshire

DIVISION V. *Hot saline highly carbonated.*

Bourbon,	}	France.
Mount d'Or,		
Vichy,		
Carlsbad, or Caroline Baths, Bohemia.		

DIVISION VI. *Vitriolated.*

Hartfell, Scotland	Haigh, Lancashire
Cashmore, Waterford	Kilbrew, Meath
Cross Town, Ditto	Nobber, Meath

Shadwell, near London	Stanger, Cumberland
Somerſham, Huntingdon- ſhire	Swanſey, North Wales

### CLASS III. SALINE WATERS.

#### DIVISION I. *Simple.*

(a) <i>common ſalt abounding.</i>	Brentwood, Eſſex
<i>Sea Water</i>	Colcheſter, Ditto
Alford, Somerſetſhire	Dog and Duck, near London
Barrowdale, Cumberland	Kenſington, Ditto
Cargyrle, Wales	Kilburn, Ditto
Dortſhill, Staffordſhire	Llandrindod, South Wales
Dublin ſalt Springs	Pancraſ, near London
Kilroot, Antrim	Richmond, Surrey
Leamington, Warwickſhire	Sedlitz, Germany
St. Eraſmus's Well, Staf- fordſhire	Sydenham, near London
	Tewkſbury, Glouceſterſh.
(b) <i>Epfom ſalt abounding.</i>	(c) <i>Alkaline ſalt abounding.</i>
<i>Epfom</i> , Surrey	Tilbury, Eſſex
Aſton, near London	Clifton, Oxfordſhire
Alkerton, near Glouceſter	Glaſtonbury, Somerſetſhire
Bagnigge, near London	St. Bartholomew, near Cork
Barnet, Hertfordſhire	Streatham, Surrey

#### DIVISION II. *Highly carbonated alkaline.*

Seltzer, Germany.

Tonſtein, Ditto.

## CLASS IV. SULPHUREOUS WATERS.

DIVISION I. *Cold.*(a) *with purging Salts.*

<i>Harrogate</i> , Yorkshire	Keddlestone, Derbyshire
Aghaloo, Ireland	Killasher, Ireland
Ashwood, Ditto	Lisbeak, Ditto
Askeron, Yorkshire	Maudeeley, Lancashire
Bilton, Ditto	Mechan, Ireland
Broughton, Ditto	Normanby, Yorkshire
Buglawton, Cheshire	Owen Breun, Ireland
Cawley, Derbyshire	Laonsbury, Yorkshire
Chadlington, Oxfordshire	Pettigoe, Ireland
Codsalwood, Staffordshire	Queen Camel, Somersetsh.
Crickle Spaw, Lancashire	Shapmore, Westmoreland
Croft, Yorkshire	Shettlewood, Derbyshire
Cunley-house, Lancashire	Shipton, Yorkshire
Derrindaff, Ireland	Sutton-bog, Oxfordshire
Derryhence, Ditto	Swadlingbar, Ireland
Derrylester, Ditto	Upminster, Essex
Drumafnave, Ditto	Wardrew, Northumberland
Drumgoon, Ditto	Wigglesworth, Yorkshire
Durham, near to	

(b) *without purging Salts.*

<i>Moffat</i> , Scotland	Llandrindod, South Wales
Carlstarphin, Ditto	Nottingham, Dorsetshire

DIVISION II. *Hot.*

Aix la Chapelle, Germany	Borset, Germany
Baden, Ditto	Mont d'Or, France
Bareges, France	

## ESSAY XXI.

## ARTIFICIAL MINERAL WATERS.

THE natural mineral waters have been so repeatedly and ably submitted to chymical investigation, that we possess now a very accurate analysis of all that are important.

This knowledge of their composition has enabled us to imitate most of them, and thus to diffuse more generally the benefits that such waters afford.

Those waters that contain only solid ingredients are very easily imitated. Such as contain gaseous substances, require more contrivance, and some of them are only to be exactly imitated by very complex and intricate processes.

This point, however, has been attained; and the artificial waters of Paul, Scheppe, and of Mr. William Henry of Manchester, may be depended upon as very accurate imitations, and as possessing all the medical virtues of the natural waters.

Those of the last gentleman I can more particularly recommend from my knowledge of his very intimate acquaintance with all chymical subjects, and his wonted accuracy in experiment; and likewise from my knowing him to have laboured of



late with peculiar assiduity in this particular branch of the science.

Our acquaintance with the composition and medical qualities of the natural waters gives us an opportunity of forming artificial ones, that differ from them in both particulars; and, by leaving out the more inert materials, to form waters more simple than the natural ones, and yet possessing the same properties as medicines.

It is only such as can be easily made, that I shall here enumerate and describe; and, for these, the only apparatus, that is required, is that invented by Dr. Nooth, and known by the name of Nooth's apparatus for making the artificial mineral waters.

#### CLASS I. *Simple Waters.*

Should the cold simple waters, as the *Malvern*, be required to be imitated, common rain water should be deprived of its chalk by boiling, and rendered still purer by distillation. This water should then be exposed to the air, that it may absorb a portion of common air, which boiling has deprived it of, and which the *Malvern* water always holds in solution. It will now only differ in holding perhaps more selenite than *Malvern* water does; but this will be very trifling, if rain or snow water has been used.

The same water heated to  $66^{\circ}$  will resemble *Matlock*, and heated to  $82^{\circ}$  *Buxton* water.

To form *Bristol* water, impregnate distilled water with fixed air, by means of Nooth's apparatus\*, and add to a wine gallon seven grains of muriated magnesia, four of common salt, and eleven of Glauber's salt. This imitation will be tolerably accurate, and when heated to  $74^{\circ}$  will possess the same properties as the natural water when fresh drawn.

To heat this and similar waters for drink, immerse a bottle of it, well corked, into hot water, till it has acquired the proper heat, which may easily be learnt after a few trials.

## CLASS II. *Chalybeate waters.*

This is by far the most extensive class, and contains the greatest variety. To imitate the simple cold carbonated chalybeates, such as that of *Tunbridge*, and a long list of others that follow it in the preceding table, impregnate distilled or even common pump water with fixed air, but not so much as for the *Bristol* water, and suspend a drachm of iron wire, or iron filings, in the middle vessel of the apparatus. The more fixed air is absorbed by the water, and the longer it remains before it is drawn off, the more iron it will dis-

\* Vide Page 131.

solve, and the more strongly chalybeate it will prove.

The highly carbonated, as *Spa*, and *Pymont*, contain much more air and iron. To imitate the first, use rain water, and for the latter a very hard water. To the first, add nine grains of magnesia and three of soda to each quart; to the latter, one scruple of magnesia, eleven grains of Epsom salt, and three of common salt, and allow them to absorb more of the fixed air than the common chalybeates, particularly for the *Pymont* water.

To imitate the *Bath water* precisely would be difficult, and perhaps in the present state of chymistry impossible, as it contains the siliceous earth in solution, which is generally considered as insoluble.

Common water very slightly impregnated with iron and fixed air (not so much so as to sparkle) when heated to  $116^{\circ}$  will not differ much in its medical qualities from *Bath water*.

The *fuline carbonated chalybeate* waters may be pretty nearly imitated, as the *Cheltenham* and *Scarborough*, by adding more salts to the common chalybeates. To each quart, for the former, add a drachm of Glauber's salt, and a drachm of Epsom salt; and, to be more accurate, impregnate it very slightly with sulphureous gas, as

will be directed presently for the sulphureous waters.

To imitate the *Scarborough* add only one third as much salts, use a harder water, and omit the sulphureous impregnation. The hot saline highly carbonated chalybeates, as *Vichy* and *Carlsbad*, are imitated by impregnating water strongly with fixed air, slightly with iron, and then adding to each pint, of Glauber's salt two scruples, common salt five grains, and mild soda 11 or 12 grains. The water is then to be heated to a sufficient temperature for use; the natural waters being too hot either for bathing or drinking when fresh drawn.

The *vitriolated chalybeates* are imitated by adding more or less of green vitriol, and a small portion of alum, to common water.

For an accurate imitation of the *Hartfell* water, first impregnate a very pure water slightly with iron and fixed air in the common way, and to a quart of this water add a scruple of green vitriol, and three grains of alum.

### CLASS III. *Saline waters.*

The simple saline waters are imitated by adding some of the purging salts to a tolerably pure water.

For *artificial sea water*, add half an ounce of common salt, and a drachm of muriate of magnesia;

to a pint of water. For *Epsom water*, dissolve a drachm of Epsom salt, and a few grains of muriate of magnesia, in each pint; and for *Sedlitz water*, add of Epsom salt five drachms, magnesia five grains, and of muriate of magnesia nine grains.

Other saline waters contain small quantities of common salt with the Epsom or Glauber's salt, or both; but, as in virtues they are nearly if not altogether similar, it is needless to describe them.

The *highly carbonated alkaline* waters are more difficult of imitation; and whoever requires good Seltzer or soda water, had better apply to the noted venders of them, than attempt an imitation.

To a pint of clear water, add five grains of magnesia, four grains of soda, and 17 grains of common salt; then impregnate with as much fixed air as possible, and the more air you make it imbibe, the nearer will it be in quality to the Seltzer water.

#### CLASS IV. *Sulphureous waters.*

The sulphureous quality of these waters depends upon the presence of inflammable air holding sulphur in solution; and to impregnate water with this sulphurated, or hepatic gas, the same apparatus and same process are required as for impregnating it with fixed air; with this difference, that



liver of sulphur must be substituted for chalk or marble.

Liver of sulphur is made by mixing equal parts of sulphur and of potash or quicklime, placing the mixture in an unglazed dish over a gentle fire, and stirring it till it forms a uniform blood-red mass.

Some of the chalybeate waters are slightly sulphureous, as we before mentioned; to imitate which some liver of sulphur must be added to the chalk in the bottom vessel.

To imitate the true *Sulphureous waters*, only liver of sulphur and the vitriolic acid are to be put into the bottom vessel; and the necessary salts, without iron, into the middle one. Most of the sulphureous waters contain so much saline matter as to prove purgative, of which *Harrowgate* water is the most noted. To imitate this you must add to each quart  $2\frac{1}{2}$  drachms of common salt, 22 grains of muriate of magnesia, and  $2\frac{1}{2}$  grains of Epsom salt.

Of those sulphureous waters, that are not purgative, the *Moffat* water stands first; which is very nearly imitated by adding 8 grains of common salt to a quart of the sulphurated water.

The artificial sulphureous and chalybeate waters, made according to the above directions, cannot be expected to be accurate imitations, because it is difficult to appreciate the quantity.

of fulphurated gas in the latter, or fixed air and iron in the former, that the water may have absorbed. They will however be found to possess the distinguishing properties, and perhaps all the medical virtues, of the natural waters.

## ESSAY XXII.

## ON THE RED WELL AT WELLINGBOROUGH.

WELLINGBOROUGH is supposed by some to be the same with Wendlynburc, mentioned by Ingulphus as one of the many towns destroyed by the Danes; but by others it is supposed to be a town of more modern date, deriving its name from the well, which we are about to treat of, the waters of which had formerly obtained very great celebrity for their medicinal virtues in the cure of a variety of complaints. Nearly two centuries ago it was in considerable repute, being noticed and recommended by Sir Theodore Mayern, a writer of that time, and physician to King Charles the first. It is likewise mentioned by Mr. John Goodyer, and by Dr. Merret; and there is a tradition, considered as tolerably authentic, that King Charles the First and his Queen resided here in tents erected on the hill, during a whole season, for the benefit of the water.

Amongst the inhabitants it has still retained considerable repute, and many of them have occasionally resorted to its water, and derived considerable advantages from the use of it.

From these circumstances, from an accurate analysis of the water, and a comparison of it with that

of Tunbridge, and other chalybeates, I believe it to be a water of considerable virtues; and I am induced to publish this account of it in hopes that it will one day recover its wonted and deserved celebrity.

Wellingborough is a well built flourishing market town in Northamptonshire, standing in a dry situation on the south side of a hill; at the bottom of which, about a quarter of a mile from the town, runs the river Nyne, a low hill or rising ground intervening.

Shoemaking and lacemaking are the chief employments of its inhabitants, the number of whom by the late calculation appeared to be about three thousand.

The well or spring, called Red well, is situated in a hollow on the top of the hill, on the south side of which the town is built. It is north west of the town, at the distance of nearly half a mile.

Its name is derived from the ochre or rust of iron deposited in its course, which gives a red appearance to the stones, weeds, and other substances, over which the water runs.

The quantity of water that the spring affords is very considerable at all seasons, sufficiently so for all the purposes it would be required for, were it as much resorted to as any of our most celebrated chalybeates.

The water has been observed to flow during very intense frosts; nor am I certain that it has ever been known to be frozen.

When fresh drawn the water is beautifully clear and transparent, but not sparkling like the Seltzer water. When drunk it has the peculiar inky flavour of all chalybeates, but not so intensely as to be disagreeable to the taste.

Its effects are to quicken the pulse, produce a general glow immediately after being drunk, and to prove gently aperient, more so than most chalybeates; beside which, it almost universally increases the quantity of urine.

The continued use of the water increases the appetite, exhilarates the spirits, improves the strength, and braces the whole system.

Like all other chalybeates it blackens the faeces of persons who drink it, which is a thing of no importance, but necessary to be mentioned, and made known to the patient, lest he take any groundless alarm.

Examined with the proper chymical reagents this water appears to differ from Tunbridge water in no respects, except that of containing rather a larger proportion of earthy ingredients, chiefly chalk (carbonat of lime), which being held in solution by the fixed air is deposited on boiling, and also by mere exposure. The deposition of this matter forms a calcareous crust intermixed with the ochre on the



sides and bottom of the basin, into which the water flows.

The other contents of the water are iron, fixed air, and a small quantity of purging salts.

The chalybeate waters sometimes produce nausea and vomiting, or headach and dizziness, on beginning a course of them; but these symptoms usually go off in a few days, particularly if the water proves aperient, and increases the flow of urine.

The water very frequently purges pretty briskly at first, but often after a long use produces a costive habit of body. When this is the case aperient medicines should occasionally be taken.

The diseases, in which the use of the Red well water promises to be of most service, are indigestion, with its various symptoms, and a variety of complaints peculiar to the female sex.

Of the latter, that debility and pallid countenance, listlessness and aversion to every kind of exercise, so frequent amongst the young, and particularly those of a delicate habit, are more speedily and certainly removed by a course of these waters than by any other means.

These waters may likewise be taken with great prospect of advantage in all cases of debility, and relaxation, from excessive discharges of any kind; provided they be not attended with fever, or with local irritation, or pain.

Of stomach complaints, flatulency, an uncertain and capricious appetite, heartburn, and all the symptoms attendant upon irregular and incomplete digestion, are such as point out the use of this class of waters; and whether they proceed from irregularity in diet; habitual smoking or chewing of tobacco, which are not unfrequent causes; from long confinement, with want of air and exercise; or from intense application, and continued inclination of the body, as in writing, reading, and many of the employments of mechanics; the continued use of this water with regular exercise and mental relaxation in different amusements, may be had recourse to with sanguine expectations of advantage.

Patients that are low and hypochondriacal, languid and inactive, with general relaxation and debility, and all convalescents from fevers, or other complaints, in whom the appetite is long in returning, may likewise expect benefit from the use of chalybeate waters.

The best mode of taking the water is to begin early in the morning with a dose of half a pint, then to walk or take other exercise for an hour, and after that to take another half pint, and to repeat the dose a third time an hour or two before dinner. This plan should be continued daily for six weeks or two months; and, if the complaints are not by that time removed, after two or three months inter-

val a second course should be gone through in the same way.

There is no occasion for any preparation previous to the use of the water, unless the stomach is judged to be foul, and then a single emetic may precede its use. If the body should be costive during the course, the water should occasionally be omitted for a day, and a gentle laxative medicine be given; or a small quantity of some purging salt may be daily added to the water.

## ESSAY XXIII.

### ON DYEING.

THE art of dyeing consists chiefly of chymical processes, and comprises a vast collection of chymical experiments. To give a detailed account of all the complicated operations of the dye-house would be tedious, and uninteresting to any but the practical dyer. Our intention is only to give the rationale of the art, and convey such general information, as shall satisfy the curiosity of the general reader, but without qualifying him for the practical department of it.

It is necessary to preface the consideration of dyeing with some observations on the substances, that are to be submitted to the operation. Wool, hair, silk, cotton, hemp, and flax, are what are principally subjected to the dyer's art.

Of these the animal productions, namely, wool, hair, and silk, are more easily dyed than the vegetable substances, cotton, hemp, and flax, because they have a stronger attraction for the colouring particles of the various dyes employed.

The animal substances are more easily injured by acids and alkalies, which makes it necessary to be more careful in the use of these, when dye-

ing or preparing for the dye such substances, viz. wool, hair, and silk.

*Wool* has a natural covering of grease, which it is necessary to deprive it of, before submitting it to the dye. This is done by scouring it with warm water, to which is added one fourth of stale chamber lie, and by afterwards washing it in a stream of clear water. The wool loses a great deal in weight by this operation, often as much as one fifth of the whole. Beside this cleansing it is generally necessary to boil the wool in a solution of alum and tartar, before it is dyed. This however is not requisite for all kinds of dyes; and then it only needs, after the above cleansing, to be washed in warm water, wrung out, and left to drain, which indeed is necessary with every other substance that we intend to dye.

*Silk* is naturally covered with a glairy varnish, which is perfectly soluble in water; and the European silk has a yellow colour, which water alone will not deprive it of; silk, therefore, is always scoured with soap and water, previous to dyeing; and to make it take and retain the colour, it is always alumed, which is done by washing it in a cold solution of alum in water.

*Cotton*, which is a vegetable production, found enveloping the seeds of certain plants, has usually in its natural state a lighter or deeper tinge of yellow, of which it must be deprived by bleach-



ing. It must then be scoured in an alkaline lie, or in sour water, which is prepared by mixing bran with water, and suffering it to remain until it ferments, and becomes sour. Afterwards, besides aluming, as with silk, it requires to be washed in a decoction of galls, or other astringent, as hot as the operator can well bear it.

*Linen*, which is made either of flax or hemp, has always a brown colour, of which it must be deprived, like cotton, by bleaching, and then undergoing the same process as we have just described.

In the art of dyeing there is a step, which is in almost all cases necessary to be taken previous to immersion of the stuff into the dyeing liquor. This is the application of what is termed a *mordant*, the nature and intention of which I shall now endeavour to explain.

In most cases it is found necessary to employ something for the purpose of making the stuff, to be dyed, take the colour more readily, and retain it more firmly; for by merely immersing the stuffs into the dyeing liquor, they will seldom take a deep dye; and the stuffs will in almost every case lose their colour again, by exposure to the air, or by washing in water. The substances thus employed, to give lustre and durability to the colours, are called *mordants*.

Different mordants are used for preparing dif-

ferent goods, and for preparing the same for different colouring drugs. Alum is by far the most extensively useful, being always employed in the printing of linens, and cottons, which is a species of dyeing now very much practised. For the dyeing of silk and wool, metallic solutions are more frequently employed as mordants.

The art of printing on cotton and linen depends chiefly on the application of the mordant. What is used for this purpose is called the aluminous mordant, being prepared by dissolving three pounds of alum in a gallon of hot water, then adding a pound of sugar of lead, stirring the mixture well at times for two or three days, and afterwards adding to it two ounces of potash, and the same quantity of chalk.

The alum and sugar of lead in this preparation are both decomposed, the sulphuric acid of the alum uniting with the lead forms an insoluble powder, which therefore subsides to the bottom, whilst the vinegar (which is the other constituent of sugar of lead) combines with the clay or alumine of the alum, and remains dissolved in the fluid. This liquor then is not a solution of alum and sugar of lead in water, but a solution of acetite of alumine, that is, a salt composed of vinegar and clay.

This mordant, being thickened with starch or gum, is applied to the cloth by blocks, or by the

pencil on those parts where the dye is afterwards intended to take, and give the pattern.

It is then dried, and afterward washed, to get out the gum or starch, and is now to be immersed into the dyeing liquor. The pattern or part, to which the mordant was applied, has a much deeper tinge than the rest, when the stuff is taken out of the liquor; and after the cloth has been repeatedly boiled in bran and water, and bleached in the air, this is the only part that retains the colour.

The use of the mordant is explained, by supposing that the particles of clay have a strong attraction for the particles of the colouring drug, and that having itself penetrated the cloth, it attracts and retains there these colouring particles. To illustrate this attraction or affinity, dissolve cochineal in a solution of alum, and then add an alkali, which will separate the clay of the alum from its sulphuric acid, and cause it to be precipitated. The clay, as it falls, attracts and carries with it to the bottom the colouring particles of the cochineal, the liquor above remaining clear and colourless.

Solutions of different metallic salts are frequently employed as mordants, having a great affinity for the colouring matter of some substances. They have a stronger attraction for animal than for vegetable stuffs, and are therefore principally used in dyeing silk and wool.

We now proceed to the consideration of the

colouring drugs, and the mode of employing them as dyes for different substances. Dr. Bancroft in treating this subject has divided the colouring drugs into substantive and adjective, the former including such as may be permanently fixed in or upon the dyed substance without the interposition either of an earthy or metallic mordant, the latter including those which require the aid of a mordant.

Others have divided this part of the subject according to the kingdom of nature, which affords the dyes, treating separately of the animal, vegetable, and mineral colouring drugs.

The division we shall adopt, which is according to the colours they afford, though perhaps less scientific, will be more congenial to our plan, as we mean to treat of the processes of dyeing, at the same time that we particularize the substances that afford the colours.

The three simple colours are red, yellow, and blue; all other colours are compounded of these. Different shades or tints of the same colour are produced by using different drugs, or by varying the quantity of colouring particles; or, in the case of the compound colours, by varying the proportion of the different simple ones, of which they are composed.

*Reds.* We shall treat of the simple colours first, and begin with RED. Cochineal, kermes, and gum lac, amongst the animal productions; and madder,

archil, carthamus, and Brazil wood, amongst the vegetables, are the chief substances employed as red dyes; and as they differ in the tint and other properties, as well as in the manner in which they are applied, we shall say a few words respecting each.

*Cochineal* is a small insect brought from Mexico, where it is found only on one plant, the cactus, or Indian fig. This is planted for the purpose, and the growth of the insect artificially encouraged. It is the principal substance now employed in dyeing the compound colour of scarlet; in considering which, the best mode of using cochineal will be mentioned.

*Kermes*, a production very much of the same nature with cochineal, gives a fine red dye to woollen goods, less vivid but more lasting than that from cochineal. It is not much used in the present day, but is seen frequently in old tapestry, where it retains nearly its original lustre. Wool must be prepared for this dye by boiling in water with one-fifth of its weight of alum, and half as much tartar, for two hours, and by being afterwards left in the same liquor four or five days; then being rinsed it is to be dyed in a warm bath, containing about twelve ounces of kermes to each pound of wool.

*Lacca, or gumlac*, a production of certain insects, something in its nature like bees-wax, is brought from the East Indies, in form either of sticklac.



seed lac, or lump lac. It is used almost solely for dyeing what is called red Morocco leather.

*Madder* is chiefly used in dyeing linen and cotton stuffs red, and by admixture with other substances in dyeing them of other colours. A very beautiful and lively red is produced by adding ox's gall to the madder bath. If the usual proportion of tartar in the preparation of the bath, which is from one seventh to one fourth, is much increased, a deep and durable cinnamon is produced.

*Archil* is sold in the form of a paste. It is made by powdering and steeping in chamber-lie and lime, either the *lichen roccella*, or the *lichen parellus*. The former called herb, or Canary archil, the latter ground or Auvergne archil. It gives a beautiful though fading lilac colour to silks, and is used, mixed with other dyes, to deepen their shades and give a bloom.

*Carthamus*, a dye made of the blossoms of a plant called *carthamus tinctorius*, cultivated in Spain, Egypt, and on the coast of the Levant, is used for giving a poppy red to silk, and in dyeing orange red, cherry red, rose, and flesh colour. When dissolved by an alkali, and precipitated by lemon juice, a powder is obtained, which, when mixed with finely pulverized talc, forms that beautiful pigment *rouge*.

*Brazil wood* imparts all its colouring matter to water by boiling; and wool, previously alumed,

is dyed a good red by gently boiling in this decoction.

**YELLOWS.** All the substances employed for dyeing yellow colours are vegetable productions. The chief are weld, fustic, arnotta, quercitron bark, and sumach.

*Weld* is prepared from the *reseda luteola* of botanists. It was very much used formerly in dyeing a yellow, but is now daily giving way more and more to the use of quercitron bark. If arnotta be added to the weld bath, a golden or jonquil colour is produced.

*Fustic* is the wood of a tree called *morus tinctoria*. According to the quantity employed it gives a yellow of different shades, from a lemon to a reddish yellow colour.

*Arnotta* is a paste procured from the seeds of an American plant called *bixa orellana*. It gives a reddish yellow, and is chiefly employed as a ground colour for other dyes.

*Quercitron bark* is got from a species of oak called *quercus nigra*. Dr. Bancroft, who first introduced it, has the sole right of importing and selling it. It contains ten times as much colouring matter as the same quantity of weld, and will probably soon entirely supersede the use of it.

*Sumach*, which is the powdered root of a plant of that name, gives a durable yellow to cottons previously prepared with the aluminous mordant.

There are many other vegetables which may occasionally be had recourse to for dyeing a yellow. The saw-wort, dyer's broom, leaves of the sweet willow, and the bark of the Lombardy poplar, may all be used for this purpose. The green outer rind of the walnut gives to wool a good fawn colour, and requires no mordant to fix it, though if a mordant be used it improves its lustre.

**BLUES.** The principal blue dyes are from indigo, woad, logwood, and Prussian blue.

*Indigo* is prepared by a long and tedious process from a plant called *indigofera*, cultivated both in America and the East Indies. One part of indigo dissolved in six or eight parts of strong sulphuric acid, and afterwards diluted with water, forms the dye called Saxon blue.

To dye silks with what is called English blue, the silk must be first dyed a light blue, then dipped in hot water, and washed in a stream, and lastly immersed in the bath composed of indigo dissolved in sulphuric acid with a small quantity of the solution of tin. And there it must be left till it has acquired the proper shade.

*Woad* is a kind of paste prepared in this country by grinding and fermenting the leaves of the *isatis tinctoria*, or, as it is called in English, the woad plant. The blue colour which it affords is much inferior in lustre, but is more permanent than that from indigo. These two dyes are mixed in forming

the blue vat or bath in which all woollen goods are dyed blue.

*Logwood*, called also *Campechy* or *Jamaica wood*, is boiled in water with a little alum, and a little verdigrise, when employed for dyeing blue; but it is much more frequently used in dyeing blacks and grays, as will presently appear.

*Prussian blue* is a chymical compound of iron and a peculiar acid, called *Prussic acid*. Both the mode of obtaining and the mode of using this dye are intricate and complicated; too much so to prove interesting in their detail. The dye which it affords is very beautiful and very durable.

**COMPOUND COLOURS.** In dyeing, the compound colours are produced sometimes by mixing the simple colours in the bath or dyeing liquor, and sometimes by dyeing the stuff first in a bath of one simple colour, then in that of another. Scarlet, green, purple, violet, and black are the compound colours that I shall now proceed to notice.

*Scarlet* is a compound of red and yellow. The most common mode of dyeing a bright scarlet is by means of the cochineal vat, which is thus prepared.

In the first place, dissolve one part of sal ammoniac in eight parts of nitric acid, at a temperature of 30° Fahrenheit's. Then add, by very small portions, one part of tin, and afterwards dilute with a fourth of its weight of water. This is now a



nitro-muriate of tin, or solution of tin in aquafortis and spirit of salt.

To make the dyeing liquor, put eighteen ounces of this solution into a tin boiler, nearly filled with clear water; then add ten ounces of tartar, and six of cochineal, and boil the mixture.

The cloth to be dyed is now to be immerfed, and the boiling continued till it has received a good colour. By adding a little turmeric, which is a yellow dyeing drug, the scarlet is rendered more lively.

Doctor Bancroft proposes to substitute quercitron bark for the tartar, and says, that a farther improvement in the scarlet dye is effected by using sulphuric acid instead of the nitric acid, or aqua-fortis, in making the solution of tin.

A good *crimson* is produced by boiling the cloth, dyed as above, in a solution of alum, or by boiling in alum and tartar first, and then dyeing with cochineal. Silk, that is to be dyed crimson, should not be thoroughly scoured, its natural yellow hue being favourable to this dye.

Articles first dyed red with madder, then in a yellow dye of weld, or quercitron bark, have a cinnamon colour.

When walnut peel is used for the yellow, the result is a chestnut, musk, or snuff colour; all of which, like scarlet, are compounds of red and yellow. Thread and cotton take a cinnamon colour.



when first dyed with verdigrise and weld, then dipped into a solution of green vitriol, afterwards into a decoction of galls, and lastly dyed in the madder bath.

*Green* is a compound of blue and yellow. To dye woollens and cottons of this colour, it is most adviseable to give the blue colour first, and then the yellow. Woad is commonly used for the former, and weld or quercitron bark for the latter. But for the Saxon green dye, indigo is the blue, and fustic the yellow, that is preferred. For very deep greens it is necessary to use logwood and green vitriol, as in dyeing blacks, only in smaller quantities.

In giving a green dye to silk, the yellow bath is first applied; and to deepen the colour, or vary its hue, decoction of logwood, fustic, or arnotta, is added to the yellow bath, after the weld has been taken out.

*Violets, purples, and lilacs*, are compounds of red and blue. In dyeing of these colours the blue ground is given first; which, even for a dark purple, should not be deeper than a sky-blue.

Logwood with galls gives several shades of purple to wool that has been previously dyed blue. Any of the red and blue dyes may be used for these colours; the selection of which, and the determining their proportions for different tints and shades.

requires a great degree of experience, and a great deal of nicety in the operator.

*Black* cannot be considered a colour, those bodies only appearing black which absorb all and reflect none of the prismatic rays. With respect to the dyer's art, however, it stands upon the same footing with any of the colours which we have mentioned.

To dye a black is as proper an expression as to dye a blue. By the first is meant to impregnate substances with such particles as shall make them capable of absorbing all the prismatic rays, and by the last is meant to impregnate with such particles as shall enable the substance dyed to absorb all but the blue rays, which being consequently reflected, produce on the organ of vision the sensation which we call a blue colour.

To give cloth a good black, it should be previously dyed a deep blue, and cleansed by fulling. It should then be dipped into a decoction of galls, and a bath of logwood and green vitriol alternately, several times successively, being exposed for a little time to the air between each immersion.

To dye silk black it must be first cleaned by boiling with soap, beetling, and washing it well; it is then to be soaked for several hours in a warm decoction of galls; and lastly immersed

three or four times in the bath of logwood and green vitriol.

*Grays* are only shades of black, and are produced by the same substances used in smaller quantities.

## ESSAY XXIV.

## OF TANNING.

THE hides or skins of almost all animals are converted to some useful purpose. The hair, wool, or fur of some is the part employed, in others it is the skin itself.

The preparation of the skins is different according to their kinds, and according to their intended uses.

The strong hides of oxen are wholly prepared by the tanner, when intended for the soles of shoes and boots; but such as are intended for harness leather, and for coach leather, are afterwards submitted to the currier's art.

The skins of horses, and of calves, are always curried, being used for the upper leathers of shoes and boots; and the skins of sheep, deer, dogs, and some other animals, are prepared for a variety of purposes by the fellmonger and leather-dresser.

The conversion of hides and skins into leather is always effected by the process of tanning, which is the art that I now intend to take into consideration.

In tanning, the object is, to convert the soft and porous hide into a hard compact substance, not easily putrescible, and in a great degree impenetrable to water; in which state it is called leather.

This object has always been chiefly effected by impregnating the substance of the hide with oak bark or tan, which is done by suffering the hides to remain immersed for a long time in an infusion of the bark in water, called by the tanners, ooze.

Different plans have been proposed and adopted in different tan-yards, for extracting the virtues of the bark, and for impregnating the hides with the same.

The grand object to be attempted is to save both bark, and time; the latter of which has been chiefly attended to by the new tanners. Before noticing, however, the late improvements, it will be right to give a concise description of what is termed the old mode of tanning, which has been adopted for many generations with scarcely any alterations, and is still most generally followed in this country.

To prepare the skins for the tan pit, they are first washed, and cleansed, if possible in running water; the loose cellular membrane is then cut away, which part of the process is called fleshing. After this, the hair is to be taken off, which is called depilation, and is effected by different means by different tanners.



Some do it by laying the skins in heaps, and leaving them together, till a putrefaction commences, which loosens the hair, and makes it very easy to be scraped off. This plan, however, requiring great care, lest the putrefaction should advance too far, and injure the skin, is pretty generally laid aside as inconvenient.

A second mode of effecting the depilation, is by immersing the skins for two or three days in lime water, and then scraping off the hair, which the lime has loosened. This plan is almost always adopted for calf skins, but for the stronger hides it is less generally approved of, because, it being necessary by washing and pressing to extract all the lime before the application of the tan, in these thick skins it becomes a laborious and tedious process.

A third mode of depilation is by immersion in an acid liquor, namely, the sulphuric acid, or oil of vitriol, very much diluted, as one pint of acid to a hundred and twenty gallons of water. After two or three days immersion the hair is loosened, and very easily scraped off.

The last improvement in this part of the business is to use the infusion or ooze, after it is become exhausted of its tanning principle, instead of water, to dilute the acid with.

After depilation there is a process called *raising*, which is often but not constantly had recourse to, with a view of opening the pores, and rendering

the hide more pervious to the tanning principle. This is done by steeping the hides in an alkaline lie, and then suffering them to remain ten or twelve hours in a vat of acid liquor, having twice as much acid in it, as that recommended for loosening the hair.

The hides and skins prepared in one or other of the above ways are now to be subjected to the *tanning*, properly so called.

The usual mode of doing this is to immerse them in pits or vats containing the oak bark, coarsely powdered, and a proper quantity of water. It is necessary to immerse them first in a weaker, then in a stronger ooze, till at last the skins are laid in alternate layers with the bark, and the pits then filled with water. The hides require twelve, eighteen, and sometimes twenty-four months immersion, to be fully saturated with the tanning principle.

During this process the hides require what is termed *bandling*, to be repeated very frequently at first, but not so often as they are advanced to the stronger oozes. This consists in removing them from the liquor, exposing them for a short time to the air, and immersing them again in the pits.

The tan by this means gets more uniformly applied to the surface of the hide, and any folds or wrinkles that are made at one time are smoothed out at another.

But, besides this, I believe handling to have other effects, in consequence of some chymical action of the air and light; for it is a fact, known to experienced tanners, that handling is more useful in a sunny day than in cloudy weather, in an exposed situation than a sheltered one, and much more so in warm than in cold weather.

From certain facts respecting the deposition of tan from an infusion of bark when exposed to the air, and certain appearances when treated with a solution of glue in close and open vessels, I am inclined to believe, that the process of handling is of much more importance than it is generally considered to be, and that hides would much sooner take the tan, if some easy means were contrived for exposing them much more frequently to the air and light; in the same way that many dyes are taken much more speedily and effectually by occasionally removing the stuff, and exposing it to the air, than if it be allowed to remain constantly in the dyeing liquor. A good black cannot be given to cloth without such repeated exposures.

Such is the usual mode of tanning. Many improvements have been proposed, some of which we shall now notice. Oak bark I have stated as the substance most generally employed, but a variety of other barks contain the tanning principle; as that of the ash, the willow, the poplar, the chestnut, &c. The barks of these trees may, and have been,

very advantageously employed in certain situations. The use of oak leaves has been proposed as a substitute for bark; and, as they would require a great deal of store-room, it has been proposed to form an extract from them, to be used as required; but I know not whether the plan has ever been adopted.

Dr. Macbride, of Dublin, recommends the use of lime water instead of plain water for making the ooze, it being well known that lime water will form a stronger infusion than plain water from the same quantity of bark. Whether it has been found to answer in tanning, I know not, but believe it to be very seldom if ever practised.

Mr. Samuel Ashton, of Sheffield, obtained a patent for a new mode of tanning, in which he professes to employ nothing but mineral substances.

An Italian has proposed the following deviations from the established mode of tanning. 1st. To soak the green hides separately in running water for a length of time, sufficient to extract all the lymph, which is known by putting a piece of the hide into water, and gradually heating it; if no scum rises to the surface, it is a proof that no more lymph remains. 2dly. To immerse them for one hour in water, heated to  $167^{\circ}$  Fahrenheit; to scrape off the hair as usual, and then expose to a stream of water at  $167^{\circ}$  till the water contains no more animal jelly, which is known by evaporating a portion of it.



3dly. To take off the loose membranous parts, wash in cold water, and then tan them in an ooze kept at  $167^{\circ}$  which has been filtered from the tan or bark.

The warm ooze has been used by several tanners in this country, but is now less approved of than at first.

The most important improvements in the art of tanning have been made by a Frenchman of the name of Seguin, and his plan is known to tanners of this country under the name of Desinond's plan.

As these improvements are grounded on the chymical qualities of the tan or bark, and on the chymical combination of the tanning principle and the hide, in the formation of leather, I shall precede an account of his plan with a few observations upon these points.

When a solution of green vitriol in water is added to an infusion or decoction of oak bark, of galls, of ash bark, or any other of the tanning barks, it immediately strikes a black colour; and such substances have been considered more or less astringent, as the vitriol has caused a deeper or a fainter black. All substances possessing this quality have been called astringent; all such substances have been considered as possessing the tanning quality; and the property of tanning, it has been concluded, depends upon this astringent principle; and hence it has been hastily inferred, that, in proportion



as the vitriol strikes a blacker colour does the astringent substance possess a stronger tanning property.

Later chymists, detecting an acid in these astringent vegetables, which they have called the gallic acid, or acid of galls, have attributed to this acid the property of striking black with vitriol, and have also considered it as the true tanning principle.

These opinions are now found to be erroneous. There are in the barks above specified, and in other vegetables, two distinct principles; the one striking a black with green vitriol, called gallic acid; the other tanning or forming leather when combined with the substance of the hide, called properly *tannin*.

These two principles exist in different proportions in different substances; and their presence is easily detected separately, by certain chymical tests. The mode of judging of the tanning quality of any particular bark by the colour produced on adding green vitriol, is therefore very inaccurate.

To detect the tannin or tanning principle in any substance, add a few drops of the solution of animal glue (made by dissolving a little common glue in water over a moderate fire) to a wine glass full of an infusion of the substance to be examined. If tannin is present, the liquor becomes turbid, and a whitish substance falls to the bottom, which is a true powder of leather, being a compound of tannin and

glue, which glue is of the same nature with the skin or hide, that by union with tannin forms leather.

The test of gallic acid is green vitriol or copperas; which, as I have before stated, strikes a black, when added to any substance containing the gallic acid.

These two principles, it is true, very frequently, perhaps always, exist together; but they exist in very different proportions in different vegetable productions, and are separable from each other.

The tannin is more soluble, and more easily extracted from the bark, than the gallic acid.

Pour water upon powdered bark; after an hour draw it off, and pour on fresh water; repeating this until the water is drawn off quite clear. This infusion contains tannin as long as it is coloured, and will cause a yellowish or whitish precipitate on addition of the solution of glue; but the clear liquor no longer contains tannin, though it still contains the gallic acid, as appears by its turning black when green copperas is added.

After these observations, the directions of Mr. Desmond, for adopting Seguin's mode of tanning, will be more easily comprehended. They are briefly as follows.

Provide five digesters, having apertures at bottom; place them near to each other, and elevate them upon stillages. Fill them with ground tan,

and pour water into the first. After standing a little time, draw it off, and pour it on the tan in the second; and so on, till it has passed them all. When this liquor, which is called the *tanning lixivium*, is drawn off from the first digester; fresh water must be poured on, and pass through all the digesters in the same way. After this is repeated several times, the liquor no longer deposits a sediment on addition of the solution of glue, and therefore contains no more tannin.

What passes after this is to be kept separately, and more water passed through, until it no longer gives a black colour with green copperas. This liquor is called the *gallic lixivium*, and is used instead of water in the process of depilation.

The tan is now completely spent or exhausted, and must be removed, that its place may be supplied by fresh. The tan in the other digesters will likewise presently be exhausted, and require to be replaced by fresh in the same manner.

The tanning lixivium should always be so strong, as to mark from six to eight degrees on the hydrometer for salts; and when, therefore, what passes from the last digester is of less strength, it must be poured upon the fresh tan in the first digester.

The hides and skins being washed and fleshed in the usual way, are immersed in a liquor formed of one part of sulphuric acid to a thousand of gallic lixivium; and the hair is then to be scraped off.

Raising is very seldom necessary; and the hides, being washed and dressed with the round knife, are fully prepared for tanning.

First steep the skins or hides for some hours in a weak lixivium of only one or two degrees, as that which runs from the second digester, or some that has been already used for tanning. Then put them into a stronger lixivium; and after a few days renew the lixivium, which will now be found to be much weaker than at first. Let it be renewed as often as it is found necessary, until the hides are quite tanned, which may be known by cutting off a small piece of the edge. Now remove the leather, and dry it in a shady place.

The peculiarity in this mode of tanning is the using a strong infusion of the tan separated from much of the gallic acid, instead of immersing the hides together with the bark in the tan pits.

The advantage of it is the saving of time, hides being tanned in this way in fewer weeks than in months according to the old plan.

Some tanners say that it requires more bark, and that the leather is of an inferior quality. Others deny this, and assert the contrary.

I believe the chief reason, why this plan is so little adopted in this country, is the uncertainty of the market. A tanner must be daily receiving fresh hides, and should therefore be regularly disposing of his leather; otherwise it lies long upon his hands,

and he loses in profit. Now in adopting this mode of tanning, which is so speedy, there must be seasons, when the tanner's stock must be immense; and of course the capital employed in such a trade must be at one time very great, whilst at another he can employ but little.

This inconvenience, added to the prejudices of old manufacturers against all innovations, has retarded the introduction of Desmond's plan very considerably.



## ESSAY XXV.

## OF CURRYING.

THE art of the currier consists in rendering the tanned skins supple and of uniform density; in giving a proper grain, and in blacking such as are required to be of that colour.

The leather, generally submitted to the currier's art, is of the thinner softer kind, as calf, seal, and dogskins, horse-hides, and the lighter cow-hides.

The stronger hides are almost solely employed for making the soles of boots and shoes, and such require no preparation after tanning but what is effected by the shoemakers, after they are cut up into pieces fit for use.

Such, however, as are intended for coach and harness leather, are prepared by the currier; and hog-hides, of which the seats of saddles are usually made, likewise undergo part of the process of currying.

After the face and ends of the shanks have been cut off, if not previously done by the tanner, the currier commences his business by soaking the skins in water, till they are completely wetted through. They are then taken out, and after draining are

placed upon short flatsided posts, called beams, to undergo what is termed the *shaving*.

The workman standing behind the beam, shaves or cuts off the loose cellular membrane from the flesh side of the skin with a round-edged knife, having a double handle, and worked with both hands. The knife is first carried lengthways, and then across the skin, from the back to the belly; and by this process the different parts are brought to a more equal substance.

The skins, thus shaved, are again immersed in water, till they are well soaked, and are then brought out to be *scoured*.

The *scouring* is generally, and ought always to be, performed at twice; the first part of the process being called *water scouring*, and the latter *fleeing*.

For this purpose the skin is stretched out upon a marble or stone slab, and the water scouring consists in pressing along it with a thin blunt-edged stone, fixed into a wooden handle, or with a lump of pumice stone; and in occasionally scouring it with a hard brush dipped in water.

The skin being again soaked in clean water, is taken out and fleeced; which flecking is done precisely in the same manner as the water scouring, except that a blunt-edged iron instrument, fixed into a wooden handle, and which is called a *flecker*, is substituted for that of stone.

The object of the scouring is to extract all the lime, and other filth, that the leather had acquired in tanning; and the use of the flecker, that is employed last, is to force out all the water, extend the skin, and obliterate the natural grain. The more the skin is extended, the finer grain will it afterwards assume.

The next part of the process is to impregnate the leather with oil, which renders it supple, and in a great measure impervious to water.

The skins for this purpose should only be half dried; and therefore in general, when scoured, they are laid in heaps till wanted. But sometimes, for the sake of dispatch, they are hung up separately in the sheds to undergo this partial drying; and this is called by the workmen *samming*.

To impregnate them with oil, or as the workmen term it, *stuff them*, they are laid out upon tables, and first the grain side of the leather is rubbed over with a mixture of cod oil, and an oil obtained from the leather dressers, called *sod oil*. Then the flesh side is rubbed over with a larger quantity of a mixture of *sod oil* and tallow, with only so much cod oil as will render it of a proper consistence to be easily spread upon the leather.

When the skins are thus stuffed, they are again hung up separately in airy sheds to dry; but before they become quite dry, they are taken down and *set*; i. e. they are stretched out upon a table, and

the neck and other coarse parts are pressed with a stone, similar to that used in scouring, with a view of extending them, taking out all wrinkles, and obliterating what may remain of the natural grain. They are then hung up again to be thoroughly dried, either in the sheds, or in stoves, according to the weather. If shed-dried they require to be exposed last of all to the sunshine.

The process of currying, as far as we have now described it, is termed by the workmen *the putting out*.

It now remains to render the leather more supple and pliable, to give it a grain, and to blacken it, if required. This part of the business is called *the making up*.

The dried skin is laid upon a large board with the grain side upwards, and being doubled is rolled with considerable pressure upon the flesh side first, and afterwards upon the grain, with a fluted board, fastened to the operator's hand by a strap. This rolling is done in the direction from the hinder flank to the cheek each way.

To take off the grease, that remains on the surface of the leather, the flesh side is gone over with a sharp flecker, and the grain rubbed with tow and the finer shavings called whitenings. To complete this object, the flesh side is slightly shaved with a fine-edged knife, which is called the *whitening*, and the grain is very highly flecked.

To give a grain to the leather, it is now rolled on the flesh side with a much finer fluted board than before, and with greater exactness.

The blacking, which is the only part of the business that remains to be described, is performed very differently on the different sides. Leather, that is to be blackened on the flesh side, which is the case with most of the finer leather for shoes and boots, is blackened with lamp-black; and what is blackened on the grain side, receives that colour from the application of copperas or green vitriol.

For the first kind a mixture of lamp-black, cod oil and allow, with a small quantity of the water in which the leather was soaked previously to the shaving, is rubbed into the flesh side with a round brush, and it is then brushed over with strong size and tallow.

When this has dried, it is flecked with a round smooth-edged glass flecker, and is lastly washed over with a weak size, to fix the colour.

The leather that is to be blackened on the grain side, after being shaved and scoured as usual, is brushed over with chamberlie, and then with a solution of green copperas. To prevent its striking too deep, it is then washed with water, and flecked out.

It is now to be stuffed as the other leather, but with a less proportion of tallow, and more seed oil.



This should be done as soon as it conveniently can, lest the copperas should injure the leather.

When it has imbibed the oil, it is not exposed to the sun, but taken down, stoned quite smooth, and again washed with the solution of copperas, till quite black.

If any artificial grain is wanted, it is now imprinted with a piece of the dried skin of the dog-fish. If the natural grain is wished for, the skin is rolled with a very fine fluted board upon the flesh side in two or three directions, and lastly upon the grain with one still finer.

The leather is now hung up to dry, either in the sun, or by the stoves, and when dried is whitened, but not with the same care that the other kind requires.

After whitening, it is again rolled with the fine fluted board, and the process is finished by rubbing it over with a small quantity of cod oil and tallow.

In blacking the leather in this way, the copperas acts the same, as when it is added to an infusion of bark or tan, which is immediately turned black by it.

THE END.

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